BOOK 204

T. NELSON

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BOOKS

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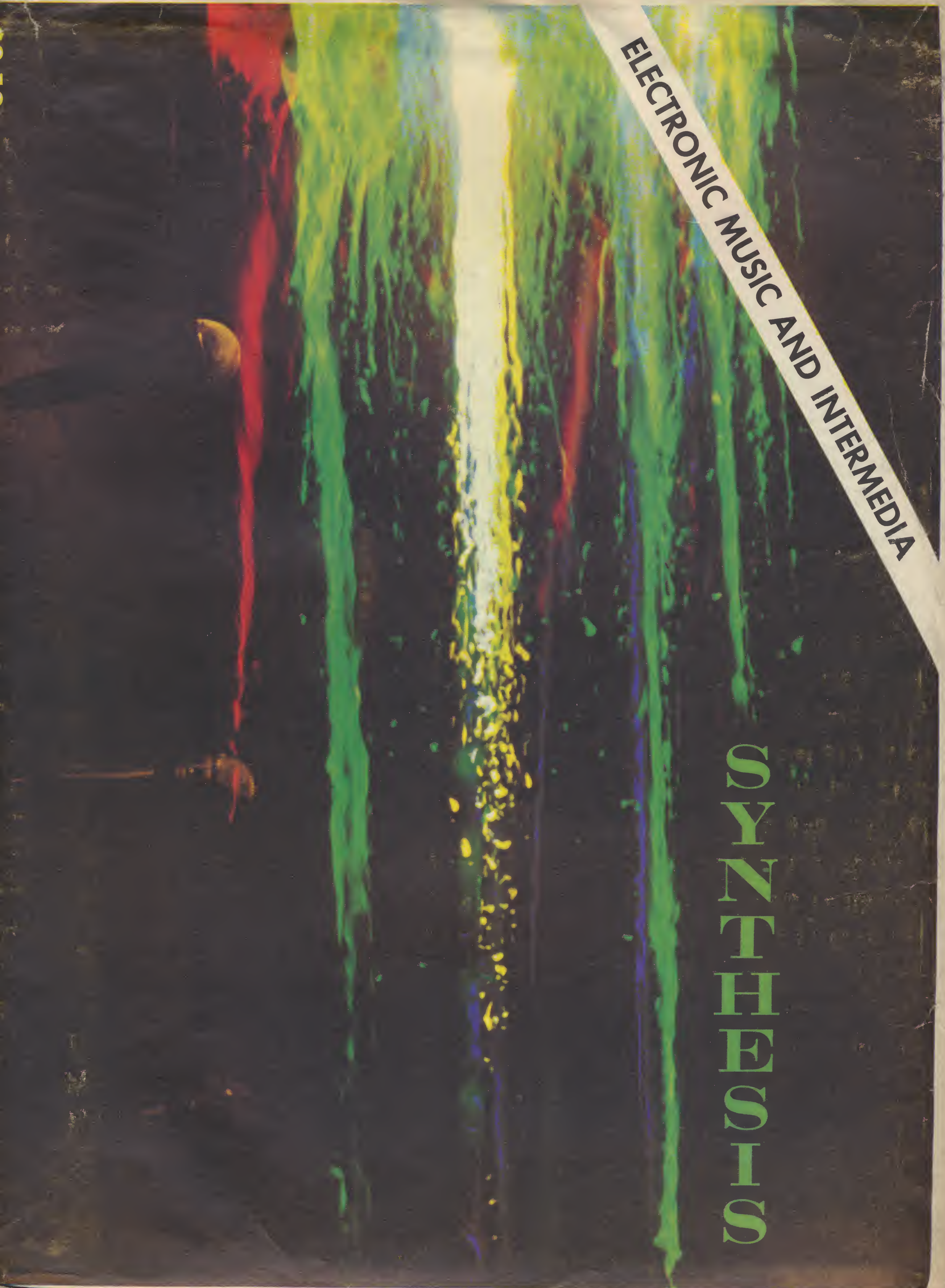
This is *not*
a bill.


ELECTRONIC MUSIC AND INTERMEDIA
SYNTHESIS

History of Electronic Music

part one

This section is meant as a hymn to the life and times of Thaddeus Cahill (1867–1934). Cahill worked for more than fifteen years to create a gigantic electrical music synthesizer before the First World War. His times have been called the childhood of our era.

The early part of the century would certainly have seemed ripe for the birth of electrical music. Books are full of labels born of that time:

atonality, bitonality, polytonality, polyrhythms, whole-tone scales, exotic scales, jazz, chords in seconds and sevenths, chords in fourths and fifths, the mystic chord, tone clusters, modality, noise music,

(someone called it the cock-sure era)

Expressionism, Impressionism,

Dadaism, Futurism, Cubism, Vorticism, Orphism, Primitivism, Post-Impressionism, Naturalism, Simultanism, Avant-Garde,

Pragmatism, Realism, Instrumentalism,

Entropy, ecology, conditioned reflex, method acting, Christian Science,

Realitivity, quantum, wave-particle, energy / matter, space / time, curved space,

Functionalism, Behavioralism, Gestalt psychology, psychoanalysis . . .

I was born to causality
and determinism, and I
have survived to
probability theory and
chance. I was born to
a world that
explained itself largely
in dogmatic terms
and I have lived, through
several changes
of management, to a world
that rationalizes
itself almost entirely
in psychoanalytic
terms.

Igor Stravinsky
Dialogues and a Diary

Speaking of the splitting
of the atom —

. . . the discovery struck me with
a terrible power, as
though the end of the world
had set in. In one moment
the mighty pillars of science
lay in ruins before me. All
things became transparent,
without power or
certainty . . . One
of the gravest obstacles on
the way to the
fulfilment of my desires
collapsed of its own
accord and disappeared.

Wassily Kandinsky

I . . . begin to feel an
irresistible drive to
become a primitive and to
create a new world.

August Strindberg
from a letter

Music may be yet unborn.

Charles E. Ives
Essays Before a Sonata

LOGIC, n. The art of thinking and reasoning in strict accordance with the limitations and incapacities of the human misunderstanding.

Ambrose Bierce
Devil's Dictionary (1906)

Since the idea of
waves is indispensable
to the account of the
propagation of light,
there could be no
question of simply
replacing it with a
corpuscular description
and one was therefore
confronted with a peculiar
dilemma whose solution
was to require a
thorough analysis of
the scope of pictorial
concepts.

Niels Bohr
Atomic Physics and
Human Knowledge

It is true that for us art
is not an end in itself,
we have lost too many of our
illusions for that. Art is
for us an occasion for
social criticism, and for real
understanding of the age we
live in . . . Dada was not a
school of artists, but an
alarm signal against
declining values,
routine and speculations a
desperate appeal, on behalf
of all forms of art, for a
creative basis on which
to build a new and universal
consciousness of art.

Hugo Ball
from his diary
(1917)

Everything appears to me
constructed . . . I am
chasing after constructions. I
enter a room, and I find
them in a corner, a
white tangle.

Franz Kafka
in a letter (1913)

Literacy had made of the
enlightened individual a
closed system, and set up
a gap between appearance and
reality which ended with such
discoveries as the streams of
consciousness.

Marshall McLuhan
The Gutenberg Galaxy

Articles, poems and polemics
were no longer adequate.
It was necessary to
change methods completely,
to go into the streets, to
launch assaults from
theatres and to
introduce the fisticuff into
the artistic battle.

Filippe Tomaso Marinetti
Guerra sola igiene del mondo
(1908)

The new painting seeks to
represent, not the
object, but the new unity;
it is a lyricism
achieved entirely by pure
pictorial means.

Georges Braque
(ca. 1912)

A certain amount of optimism seems understandable. Some of the scientific achievements during the last quarter of the nineteenth century were:

1876 - Invention of the telephone
1877 - Invention of the phonograph
1879 - Invention of the incandescent light
1882 - First public supply of electricity (in NYC)
1885 - Boston connected to New York by telephone
1887 - First sale of a gasoline-engine automobile (in Germany)
1888 - Invention of the induction motor
1888 - Invention of roll-film for the camera
1889 - First showing of a motion picture
1894 - Niagara Falls harnessed to produce electricity
1895 - First transmission — reception of radio waves
1895 - Discovery of X-rays
1896 - Discovery of radioactivity
1897 - Discovery of the electron
1899 - First recording of sound (magnetically) on wire and on a thin metal strip

By 1900 the entire civilized world was connected by telegraph, and there were more than 1.4 million telephones, 20 million electric lights, and 8,000 registered automobiles in the United States.

By 1900 the Gramophone Company was advertising a choice of five thousand recordings . . . There were separate lists of English, Scotch, Irish, Welsh, French, German, Italian, Spanish, Viennese, Hungarian, Russian, Persian, Hindi, Sikh, Urdu, Arabic, and Hebrew records. The Italian catalogue put special emphasis on opera: by early 1900 all the major arias and duets — and a fair number of minor ones too — could be found in its pages . . . In September 1902, [they] published its first Red Label Catalogue, an expensive-looking brochure printed on heavy paper and generously illustrated with pictures of Red Label artists. Except for the violinist Jan Kubelik, the musicians represented therein were all opera singers. It was, after all, the Golden Age of Opera, an epoch when no mere instrumentalist could approach the glamorous aura of the cherished singer. Moreover, the recording technique then in use dealt far more kindly with the human voice than with musical instruments . . .

Roland Gelatt
The Fabulous Phonograph

Education ran riot at Chicago, at least for retarded minds which had never faced in concrete form so many matters of which they were ignorant. Men who knew nothing whatever — who had never run a steam-engine, the simplest of forces — who had never touched an electric battery — never talked through a telephone, and had not the shadow of a notion what amount of force was meant by a watt or an ampere or an erg, or any other term of measurement introduced within a hundred years had no choice but to sit down on the steps and brood as they had never brooded on the benches of Harvard College . . . The historical mind can think only in historical processes, and probably this was the first time since historians existed, that any of them had sat down before a mechanical sequence.

Henry Adams
The Education of Henry Adams

The world has changed less since Jesus Christ than it has in the last thirty years.

Charles Peguy
(1913)

Anything that is approached in depth acquires as much interest as the greatest matters. Because "depth" means "in interrelation," not "in isolation."

Depth means insight, not point of view; and insight is a kind of mental involvement in process that makes the content of the item seem quite secondary.

Marshall McLuhan
Understanding Media

The artist of the modern movement is a savage (in no sense an 'advanced,' perfected democratic, futurist individual of Mr. Marinetti's limited imagination): this enormous, jangling, journalistic, fairy desert of modern life serves him as Nature did more technically primitive man.

Wyndham Lewis and Ezra Pound
Blast (1914)

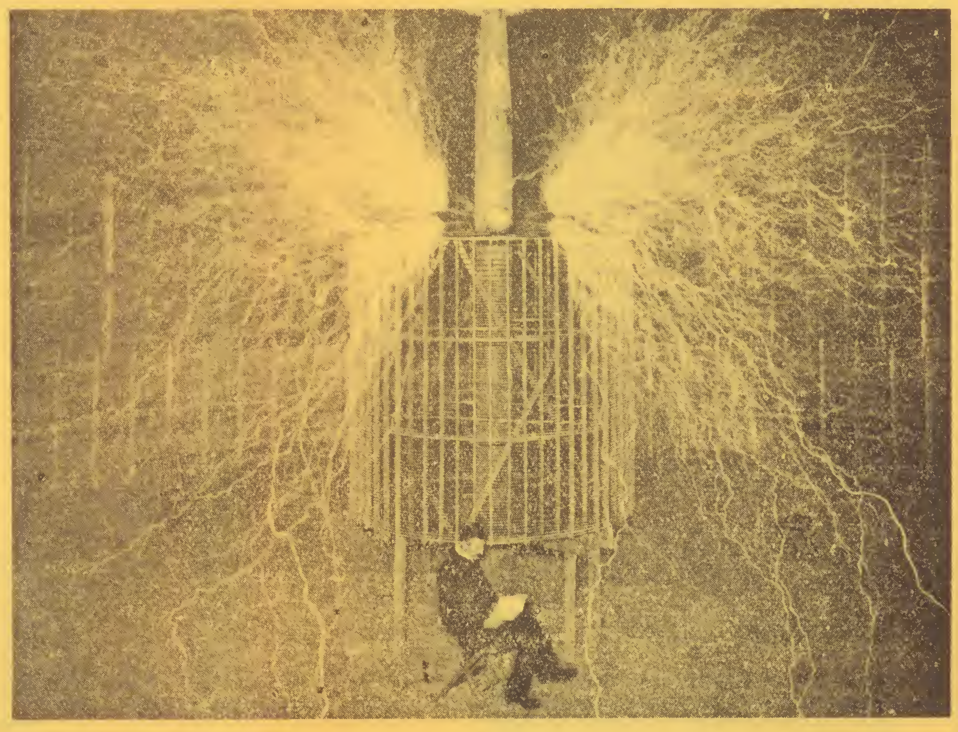
I cannot believe . . . that God plays dice with the world.

Albert Einstein

At a time like ours, in which mechanical skill has attained unsuspected perfection, the most famous works may be heard as easily as one may drink a glass of beer, and it only costs ten centimes, like the automatic weighing machines. Should we not fear this domestication of sound, this magic that any one can bring from a disk at his will? Will it not bring to waste the mysterious force of an art which one might have thought indestructible? Why don't they understand that there is really no reason to have so many centuries of music behind us, to have thus profited by this magnificent intellectual heritage and to seek childishly to re-write history? Is not our duty, on the contrary, to find the symphonic music appropriate to our age, that which is demanded by progress, bravery and modern victories? The century of aeroplanes has a right to a music of its own.

Claude Debussy
La Revue S.I.M.
(1913)

While Cahill was working on his synthesizer, Nicola Tesla — who had invented the induction motor and had done considerable work on electrical distribution systems — was out in Colorado with giant transformers trying to set the planet earth in oscillation.



Jules Verne had just died and H. G. Wells was in his prime.

If the air seemed extraordinarily open to new possibilities, there was also considerable talk of the collapse of something well established. Theoretical physics was effecting what has been called the Second Scientific Revolution. And if the discoveries of the atomic physicists were not directly the progenitors of thought in other fields, they certainly seemed rich in applicable metaphors.

With the new vision, the universe was composed of an utterly democratic world of incredibly small energy-matter bits moving at or near the speed of light. At this level of "true reality" the classically simple cause-effect relationship had to be abandoned. The bits exerted fantastically complex spheres of influence or overlapping fields, and one could not observe a phenomenon without altering it. All matter was really a form of energy. All observations were relative to individual positions in space/time.

This experience gave me also
an opportunity to learn
a fact — a remarkable one in
my opinion: a new
scientific truth does not
triumph by convincing its
opponents and making them
see the light, but rather
because its opponents
eventually die, and a
new generation grows up
that is familiar with it.

Max Planck
Scientific Autobiography and other papers

Naturally it was a
fierce struggle, there were
inhibitions of the most
fearful kind to overcome, a
panic fear as to whether it
was possible . . . You're
listening to someone who
has experienced and
fought for all these
things. All these events
tumbled over one another;
they came upon us
unselfconsciously and
intuitively.
And never in music has such
resistance been shown as there
was to these things.

Anton Webern

In the 1860's Maxwell had solidified an area called field physics by working out some equations for the propagation of electromagnetic waves. To many, the laws of Newton and Maxwell had made of physics a closed book. All the laws were known and only the details needed to be filled in. Newton's laws took care of mass, forces, steady-states, fixed positions, and normal cause-effect relationships in what was called a "mechanical" universe. Maxwell's equations covered the newly discovered electromagnetic fields. Many felt we "understood" nature.

Then came the splitting of the atom, quantum mechanics, the theory of relativity, and the necessity of applying the laws of probability and chance to explain measurable occurrences in nature. Suddenly there was talk of effects preceding causes, of the abolition of the concept of force, of space/time and energy/matter continuums, of curved space, and of wave-particles (that is, electrons had to be considered as waves sometimes and particles other times — depending on which aspect of their behavior one was trying to explain.) A considerable struggle ensued in which Maxwell's equations held, but Newton's laws were found to be approximations which could only be used when the mass involved was not too small, nor the speed too great.

It is said that a mechanical view of the universe yielded to a field view.

When the air had cleared a bit (it is, in 1970, still anything but clear) the new concepts seemed so ripe in consequences for man's social and psychical life that many of the key figures in the revolution wrote of the philosophical consequences. Innumerable books by others have been written.

In part, what the scientists were pointing out again and again was that science does not deal in *truths* (that is, any sort of ultimate knowledge) but only in certain mathematical abstractions which make it possible for us to manipulate our environment.

It was as if the ground had
been pulled out from
under one, with
no firm foundation
to be seen anywhere,
upon which one
could have built.

Albert Einstein

The old absolutists
perpetrated a . . . naivete in every
sphere of thought. They began
with an excessive estimate of
man.

Ortega y Gasset
The Modern Theme

The "thing-in-itself"
is for the atomic physicist,
if he uses
this concept
at all,
finally a mathematical
structure;
but this structure is –
contrary to Kant –
indirectly deduced
from experience.

Werner Heisenberg
Physics and Philosophy

The nearer any subject
or an attribute of it
approaches to the
perfect truth at its
base, the more does
qualification become
necessary.

Charles E. Ives
Essays Before a Sonata

An image can be placed
somewhere between these
two antipodes:
Realism=Abstraction
Abstraction=Realism

Wassily Kandinsky
The Problem of form (1912)

You are looking into a
fog and for that reason
persuade yourself that
the goal is already
close. But the fog
disperses and the goal
is not yet in sight.

Ludwig Wittgenstein
Notebooks (1915)

I am separated from all
things by a hollow
space, and I do
not even reach
to its boundaries.

Franz Kafka
in a Letter
(1911)

One thing which emerges is that physics tells us much less about the physical world than we thought it did. Almost all the 'great principles' of traditional physics turn out to be like the 'great law' that there are always three feet to a yard; others turn out to be downright false.

Bertrand Russell, *The ABC of Relativity*

It was a golden age for tracts and manifestos:

Der Sturm, Blast, Dada,
Lacerba, La Voce, 291, 391,
Die Aktion, Futurist Manifesto,
Imagist Manifesto,
L'Antitradition futuriste,
Das Kunstblatt . . .

And from the excerpts we have seen, some artists were going beyond self-justification or mere references to their art and calling for a complete social upheaval led by artists.

Attacks were leveled against systems, against reason, against abstractions, against unhealthy social attitudes allegedly based wholly on fictions.

It seems as though the world was suddenly found to be more complex than previously believed. Some felt that if the facade of rational "understanding" (meaning here the measuring of things against the old fixed systems) could be given up a new "dynamic" foundation could be built.

The concepts of Darwin and Freud have been called the last straws in the devaluation of man's self-image.

Nietsche had said that everything would have to be redefined.

Those who sensed an awareness of a new vision could easily find old concepts which seemed harmful. But, despite the intuitive leaps into the new world, there seems to have been very little of any solid foundation upon which to begin a careful process of redefinition.

For all the crusading optimists, there were those who felt deeply disinherited. T. S. Eliot said, "The only way is to be very intelligent."

The myth that everything in the
world can be rationally
explained had been gaining
ground since the time of
Descartes. An inversion
was necessary to restore the
balance. The realization
that reason and anti-reason,
sense and non-sense,
design and chance,
consciousness and
unconsciousness belong
together as necessary
parts of a whole — this was
the central message of Dada.

Hans Richter
Dada

Everything is illusion:
family, office, friends,
the street, the woman, all
illusion, drawing nearer
and further away; but the
nearest truth is merely that I
push my head against the
wall of a cell without
doors or windows.

Franz Kafka
Gesammelte Schriften

In short,
must a song always be a song!

Charles E. Ives
Postface to 114 Songs

Some violence is inevitable when men are called on, in any sphere, not to *correct* their previous ideas by removing some error, but actually to move forward to a new plane that includes, rather than replaces, the old. In the moral sphere, what was until now simply "good," is seen for the first time no longer as an absolute, but also as the enemy of a better — and yet it has still also to be grasped as good.

Owen Barfield, *Saving the Appearances*

Because he was threatened
with a "loss of faith
in conceptual thought."
Hofmannsthal turned (in 1902)
to other media that do not
demand the rendering of
immediate experience;
and refused to contribute to
the development of
modernist poetry.

Michael Hamberger
Reason and Energy

The new playwrights Sorge, Kornfeld, Hasenclever, Barlach, Sternheim, Kaiser, Werfel, Kokoschka, Goering, Goll, Csokor, Bronnen, Toller, Wolff, Brecht, and many others despite profound differences in spirit and form, seemed to have this in common:

they rebelled against propriety and "common sense," against authority and convention in art and in life. They rejected the tradition of the "well-made play," and the canons of plausibility and "good taste" in art.

Walter H. Sokel
An Anthology of German Expressionist Drama

speaking about Ulysses

. . . the task I set myself
technically in writing a
book from eighteen different
points of view and in as many
styles all apparently
unknown or undiscovered by
my fellow tradesmen, that and
the nature of the legend
chosen would be enough
to upset anyone's
mental balance.

James Joyce
from a letter

The literate man or society develops the tremendous power of acting in any matter with considerable detachment from the feelings or emotional involvement that a nonliterate man or society would experience.

Marshall McLuhan
Understanding Media

Melancholy

Striding striving
Living longs
Shuddering standing
Glances look for
Dying grows
The coming
Screams!
Deeply
We
Dumb.

August Stramm

To understand the climate in which Dada began, it is necessary to recall how much freedom there was in Zurich, even during a world war. The Cabaret Voltaire played and raised hell at No. 1 Spiegelgasse. Diagonally opposite, at No. 12, Spiegelgasse, the same narrow thoroughfare in which the Cabaret Voltaire mounted its nightly orgies of singing, poetry and dancing, lived Lenin. Radek, Lenin and Zinovier were allowed complete liberty. I saw Lenin in the library several times and once heard him speak at a meeting in Berne. He spoke good German. It seemed to me that the Swiss authorities were much more suspicious of the Dadaists, who were after all capable of perpetrating some new enormity at any moment, than of these quiet, studious Russians . . . even though the latter were planning a world revolution and later astonished the authorities by carrying it out.

Hans Richter
Dada

It perhaps contradicts much of the thought of the period to speak of origins or first causes. Most writers go deep into the nineteenth century for substantial roots. Whitehead speaks of the advance in measuring instruments made possible during the industrial revolution. Korzybski speaks of the new systems of geometry which removed Euclidian geometry from the realm of the absolute ("*the* geometry became *a* geometry"). McLuhan, of course, emphasizes the onrushing electrical, technology and speaks of an implosion.

William James said of Pragmatism: "The pragmatic movement, so-called — I do not like the name, but apparently it is too late to change it — seems to have rather suddenly precipitated itself out of the air. A number of tendencies that have always existed in philosophy have all at once become conscious of themselves collectively, and of their combined mission; and this has occurred in so many countries, and from so many different points of view, that much unconcerted statement has resulted."

. . . it is by accident —
chance or convention,
as you please —
that science obtains a hold
on the living analogous
to the hold it has on
matter.
Here the use of conceptual
frames is no longer natural.

Henri Bergson
Creative Evolution
(1911)

in Lipp's words:
The unconscious is the true
psychical reality; in its
innermost nature it is as
much unknown to us as
the reality of the external
world, and it is as
incompletely presented by
the data of consciousness
as is the external world
by the communications of our
sense organs.

Sigmund Freud
The Interpretations of Dreams
(1900)

Animals trustingly stepped
into his open glance, grazing ones,
even the lions long captive
entered it staring, an incomprehensible freedom;
birds flew through it unswerving,
it that could feel them. And flowers
mirrored themselves in it,
great as in children.

Rainer Maria Rilke, from *Wendung* (1914)

I don't hold any opinions,
my views are impromptus.
Life would be pretty
monotonous if one
thought and said the
same things every day.
We've got to keep it
new and fresh. One's
whole life, after all,
is only a poem.

August Strindberg
The Cloister (1898)

The best musician I know admitted
that his sense of precise aud-
ition was intermittent.
But he put it in the form *moi
aussi*, after I had made my own
confession.
When you get to the serious con-
sideration of any work of art,
our faculties or memories or
perceptions are all too
'spotty' to permit
anything save mutual
curiousity.

Ezra Pound
ABC of Reading

The provincial spirit has always, and with good reason, been accused of stupidity. Its nature involves an optical illusion. The provincial does not realize that he is looking at the world from a decentralized position. He supposes, on the contrary, that he is at the centre of the whole earth, and accordingly passes judgment on all things as if his vision were directed from that centre . . . The theory of Einstein has shown modern science, with its exemplary discipline – the *nuova scienza* of Galileo, the proud physical philosophy of the West – to have been labouring under an acute form of provincialism.

Ortega y Gasset, *The Modern Theme*

CARTESIAN, adj: Relating to Descartes, a famous philosopher, author of the celebrated dictum, *Cogito ergo sum* – whereby he was pleased to suppose he demonstrated the reality of human existence. The dictum might be improved, however, thus: *Cogito cogito ergo cogito sum* – "I think that I think, therefore I think that I am;" as close an approach to certainty as any philosopher has yet made.

Ambrose Bierce
Devil's Dictionary

My God! What has sound
got to do with music!

Charles E. Ives
Essays Before a Sonata

Many call the present sit-
uation in art "anarchy."
Here and there the same word
is used for today's music.
In this way people wrongly en-
vision a purposeless subver-
sion and chaos. But anarchism
actually signifies planning
and order, though not by
external force or coercion
but by an intuition of the
Good. Here too there are
limits, but these limits
are steadily being ex-
tended. In this way
freedom grows and creates that
open road which leads to the
Spirit. Contemporary art,
which can be called
anarchistic in the above
sense, not only reflects
the present spiritual level of
the world but it embodies as
a creative energy that
next spiritual level
which is ripe for
revelation.

Wassily Kandinsky
The Problem of Form (1912)

. . . the technique of the sus-
pended judgment, the great dis-
covery of the twentieth century
in art and physics alike, is a re-
coil and transformation of the
impersonal assembly-line of
nineteenth century art and
science.

Marshall McLuhan
The Gutenberg Galaxy

Western music also had a long tradition of theoretical abstractions more or less considered to be based on natural laws: tonality, related keys, appropriate treatment of dissonance, etc. And the established musical theory (perhaps like the relationship of Newton's laws to nature) held up remarkably well in "explaining" (at least not contradicting) the practice of the masters of the Western musical tradition.

Rameau attempted,
with more or less success,
to cast his theory into a
scientific form . . . His principles
are to be *natural* principles;
they must have their
source in Nature and have, there-
fore, all the certainty of
natural laws. He has endeavored,
as he himself tells us, to
free himself from all precon-
ceived notions imposed by
rules derived merely from tradi-
tion, from "custom and author-
ity." Reason, truth, fidelity
to Nature, these were the guides
that he felt himself impelled
to follow. In all this Rameau
was undoubtedly strongly in-
fluenced by the intellectual
forces of his age . . . the
influence of the Cartesian
"method" may be easily
traced.

Matthew Shirlaw
Theory of Harmony

And, as also seems to have been the case with Newton's laws, the prevailing musical theory was apparently prone to creating a false security in many people who were not terribly aware that most of reality was not being subjected to analysis.

At any rate, the "common practice" had been slowly disintegrating for some time. Around the turn of the century the concepts themselves were open to general questioning. Debussy is said to have used "nonfunctional" harmony. Schoenberg claimed to have "emancipated the dissonance." Music could be conceived as "atonal." Ives is said to have parodied allegiance to classical forms. Etc.

Possibly the immobility of
the things around us has merely
been imposed on them by our
certainty that they are what
they are and nothing else, by
the immobility of our
thinking about them.

Marcel Proust

Every normal man — that is, every uncivilized or civilized human being not of defective mentality, moral sense, etc. — has, in some degree, creative insight (an unpopular statement) and an interest, desire and ability to express it (another unpopular statement). There are many, too many, who think they have none of it, and stop with the thought, or before the thought. There are a few who think (and encourage others to think) that they and they only have this insight, interest, etc., and that (as a kind of collateral security) they and they only know how to give true expression to it, etc. But in every human soul there is a ray of celestial beauty (Plotinus admits that), and a spark of genius (nobody admits that).

Charles E. Ives, *Postface to 114 Songs*

In fact we have to
break new ground
with each work . . .
Anton Webern

A pragmatist turns his back
resolutely and once for all
upon a lot of inveterate
habits dear to professional
philosophers. He turns
away from abstraction and
insufficiency, from
verbal solutions, from
bad a priori reasons, from
fixed principles, closed
systems, and pretended
absolutes and origins.
He turns towards
concreteness and adequacy,
towards facts, towards action
and towards power . . .
It means the open air and
possibilities of nature,
as against dogma,
artificiality,
and the pretence
of finality in truth.

William James
Pragmatism (1907)

I live in terrible noise.
I have been under fire.
Marvellous!
Ten days of
marching in high mountains
with cold, hunger,
thirst! . . .
Sleeping in the open in the
rain at 1400 [metres] . . .
240 [pieces of] shrapnel have
fallen on my unit . . .
received with ironical
laughter . . . War is a
wonderful, marvellous,
terrible thing! In
the mountains it . . . seems
like a fight with the
infinite. Grandiosity,
immensity, life and
death! I am happy!

Umberto Boccioni

I tried to peg out soldierly, —no use!
One dies of war like any old disease.
This bandage feels like pennies on my eyes.
I have my medals? —Discs to make eyes close.
My glorious ribbons? —Ripped from my own back
In scarlet shreds. (That's for your poetry book.)

Wilfred Owen
from *A Terre* (1918)

I cannot draw an
unconditional distinction
between sound colour and
sound pitch, as it is usually
expressed. I find that the
note makes itself heard
through the sound colour, of
which the sound pitch is a
dimension. So the colour
is the large area, the
pitch is a part
of it.

Arnold Schoenberg
Harmonielehre (1911)

It is essential to
abandon the over-valuation
of the property of being
conscious before it becomes
possible to form any correct
view of the origin of what
is mental.

Sigmund Freud
The Interpretations of Dreams
(1900)

The world was, of course, far more rich than we have indicated here. According to Ortega, the population of Europe almost tripled from 1800-1914 — there seems to have been a market for everything. In music, for instance, there were Puccini, Strauss, Mahler, Satie, John Philip Sousa, Irving Berlin, George M. Cohan, Jelly Roll Morton, etc., etc., etc. (Tin Pan Alley claims to have sold two billion copies of sheet music in the year 1910.)

The aim . . . is not for the child to go to school as a place apart, but rather in the school so to recapitulate typical phases of his experience outside of school, as to enlarge, enrich, and gradually formulate it.

John Dewey
The School and Society (1900)

Comparison of the costs of the unit under different conditions is perhaps the best starting-point for a campaign to reduce unit costs or to improve the quality of units of service.

Every school system presents within itself abundant opportunity for the comparison of unit costs . . . Why is a pupil recitation in English costing 7.2 cents in the vocational school while it costs only 5 cents in the technical school? Is the "vocational" English 44 per cent superior to the "technical" English or 44 per cent more difficult to secure?

Frank Spaulding
N.E.A. Proceedings (1913)

I may have exaggerated somewhat in order to make plain the typical points of the old education: its passivity of attitude, its mechanical massing of children, its uniformity of curriculum and method. It may be summed up by stating that the center of gravity is outside the child. It is in the teacher, the textbook, anywhere and everywhere you please except in the immediate instincts and activities of the child himself.

John Dewey
The School and Society (1900)

Compulsory education was also relatively new and advice to the educators was plentiful.

In the margins of this page are quotes by John Dewey (left) and others (right) taken from the period. McLuhan said that John Dewey was "in a very confused way, trying to explain the meaning of the electric age to educators." The quotes on the right were taken from a book called *Education and the Cult of Efficiency* by Raymond E. Callahan. According to the author (the book is meticulously documented) the attitudes on the right were in the overwhelming majority.

There is no question that the average individual accomplishes the most when he either gives himself, or some one else assigns him, a definite task, namely, a given amount of work which he must do within a given time. . . No school teacher would think of telling children in a general way to study a certain book or subject. It is practically universal to assign each day a definite lesson beginning on one specific page and line and ending on another; and the best progress is made when the conditions are such that a definite study hour or period can be assigned in which the lesson must be learned.

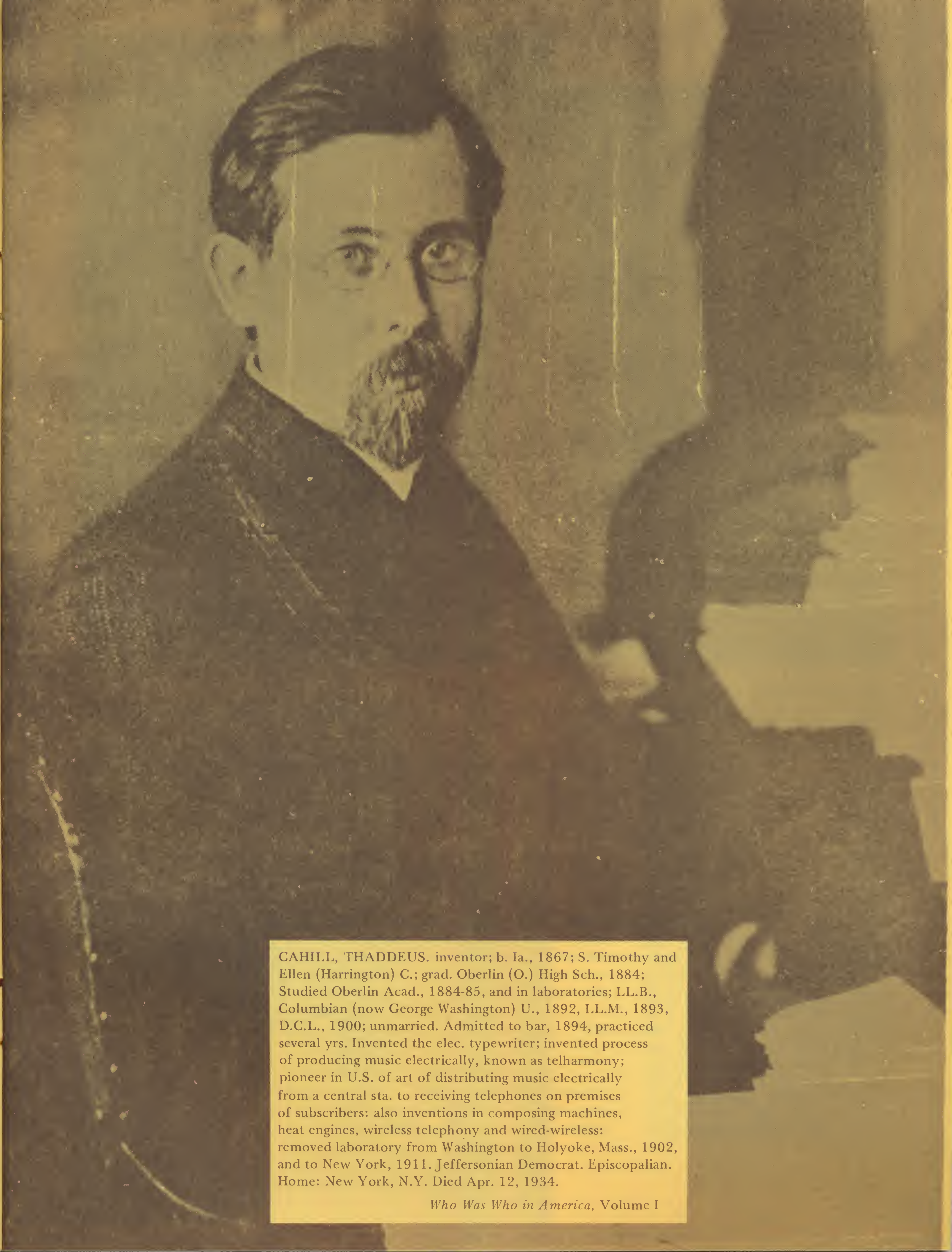
Frederick W. Taylor
Shop Management (1912)

Abandon the notion of subject-matter as something fixed and ready-made in itself, outside the child's experience; cease thinking of the child's experience as also something hard and fast, see it as something fluent, embryonic, vital; and we realize that the child and the curriculum are simply two limits which define a single process.

John Dewey
The Child and the Curriculum (1902)

Ordinarily a love of learning is praiseworthy; but when this delight in the pleasures of learning becomes so intense and absorbing that it diminishes the desire, and the power of earning, it is positively harmful. Education that does not promote the desire and power to do useful things — that's earning — is not worth getting. Education that stimulates a love for the useful activity is not simply desirable; it is in the highest degree ethical . . .

N.E.A. Proceedings (1909)



CAHILL, THADDEUS. inventor; b. Ia., 1867; S. Timothy and Ellen (Harrington) C.; grad. Oberlin (O.) High Sch., 1884; Studied Oberlin Acad., 1884-85, and in laboratories; LL.B., Columbian (now George Washington) U., 1892, LL.M., 1893, D.C.L., 1900; unmarried. Admitted to bar, 1894, practiced several yrs. Invented the elec. typewriter; invented process of producing music electrically, known as telharmony; pioneer in U.S. of art of distributing music electrically from a central sta. to receiving telephones on premises of subscribers: also inventions in composing machines, heat engines, wireless telephony and wired-wireless: removed laboratory from Washington to Holyoke, Mass., 1902, and to New York, 1911. Jeffersonian Democrat. Episcopalian. Home: New York, N.Y. Died Apr. 12, 1934.

Who Was Who in America, Volume I

Thaddeus Cahill became intensely interested in the physics of musical sounds during his teens and conceived the idea of creating a perfect musical instrument. He noted that all existing instruments had limitations: pianos had a limited power to sustain tones, violins were limited in chord-playing, organs could do little to influence a tone once keys were depressed, and so forth. He felt that electricity might enable him to build an instrument which could give the performer absolute control over all musical materials.

In 1881 (at the age of 14) he built his own telephone receiver after the Bell company refused to sell him one for his experiments. Encouraged by his father and two brothers, he dropped out of college (Oberlin) at 18 to devote more time to his inventions. Private tutors were hired to assist in his formal education.

At the age of 23 he moved to Washington, D.C., where he worked as a clerk in the House of Representatives and enrolled in evening courses at Columbian University. (He was admitted to the Bar in 1894 and received the degree D.C.L. in 1900.) During this period he produced an electric typewriter and built the first prototype of his musical machine, sometimes employing two draftsmen to keep pace with his work. (He had an "iron constitution and the tenacity of a genuine purpose." — Ray Stannard Baker.)

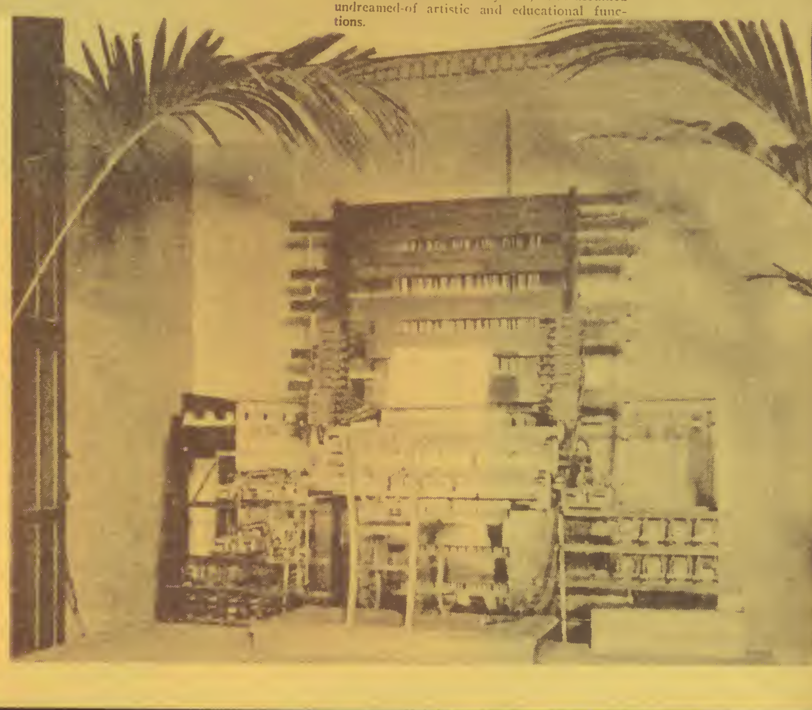
He filed for the first patent on his musical machine in 1895. By then, his idea had grown to include a vast network in which music was to be generated on a perfect instrument at a central plant and distributed on leased telephone wires to the homes and businesses of paying subscribers. The essence of his idea is complete in this first patent; subsequent lengthy patents describe his agonized search for refinements as he moved from early rheotomes to meticulously machined alternators, from belt-drive to innumerable combinations of gearing mechanisms, from simple sine tones to investigations of complex tones with harmonics up through the 64th, from simple on-off switches to elaborate "expression devices" involving a swell pedal, a touch-sensitive keyboard, a small keyboard with each key representing a discrete dynamic level, etc.

Cahill as a young man.

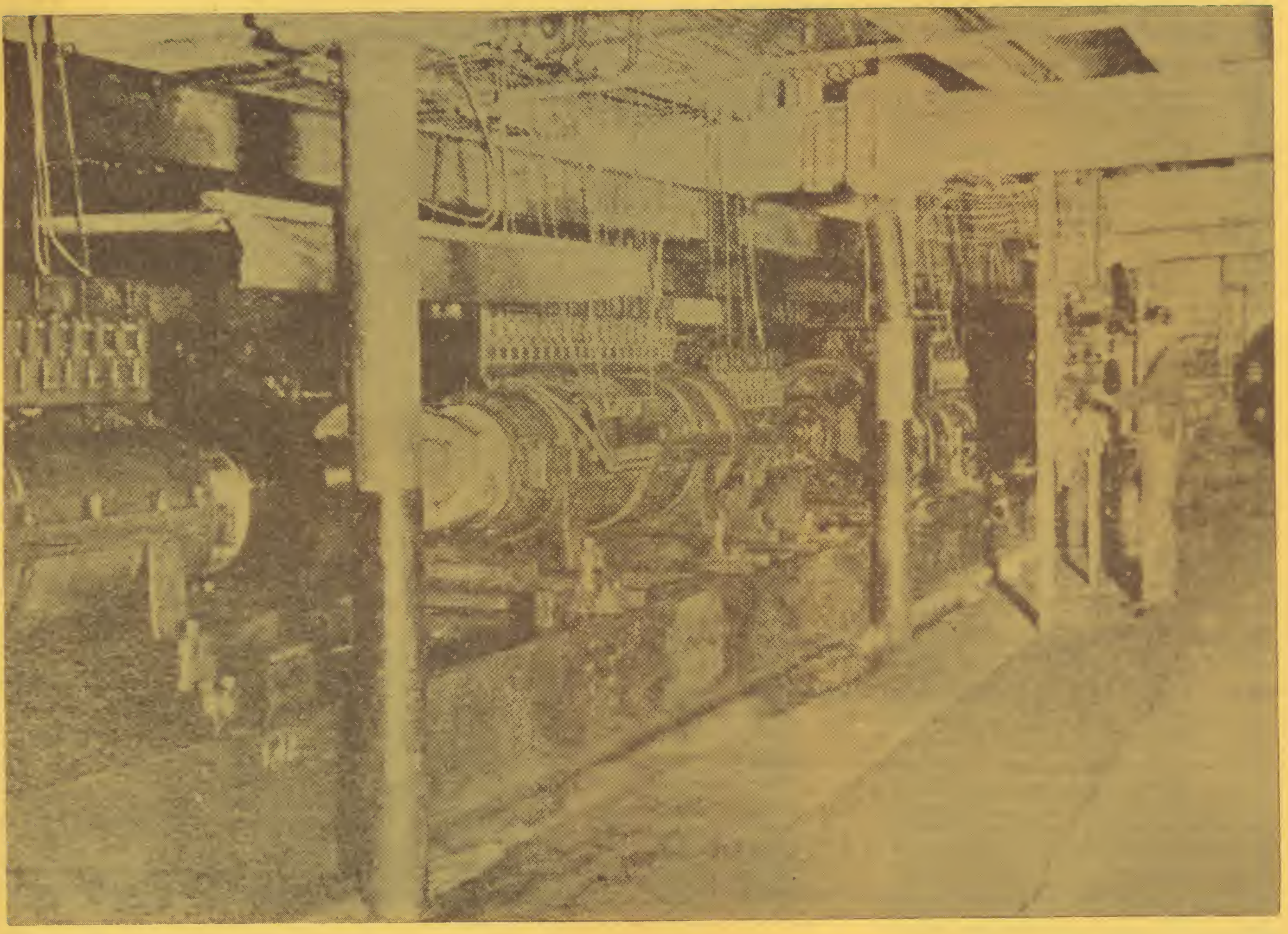
CURRENT LITER.

THE DEMOCRACY OF MUSIC ACHIEVED BY INVEN

HUMAN slavery is immoral. On the slavery of the machine the future of the world depends." It is thus that a great artist has pictured to himself the advance of human progress. Not content with the application of mechanical forces to utilitarian purposes, human ingenuity has, within recent years, lifted the activity of the machine into the sphere of art. It is in music especially that the spirit of man, Ariel-like, guides the sightless demons of strength—Calibans of mechanics—and out of the mouth of a machine conjures the miracle of song. The numerous piano-players, the phonographs and—latest and most elaborate—the Telharmonic System, have assumed undreamed-of artistic and educational functions.



Keyboard of the Cahill Telharmonium in the Central Music Station



THE BASIC CONCEPT

Cahill's machine was predicated on three rather recent developments:

Five years before his birth Helmholtz had demonstrated by careful experiments that a complex musical tone is composed of many different simpler tones called harmonics. What we identify as an oboe playing middle c (c′=256 Hz) is partly the result of individual responses of little hairs in our ears, some of which are responding to 256 Hz, and some to other frequencies above that pitch. These higher frequencies are consecutive integer multiples of the fundamental (or first harmonic). That is, our ear responds to the fundamental (256 Hz – c′), the second harmonic (512 Hz – c″), the third harmonic (768 Hz – g″), etc. What we call tone color (or timbre) is the result of the relative intensities of these harmonics. Each of the harmonics is individually represented by a simple sine wave – the complex tone being represented by a more complex wave resulting from adding all the individual sine waves together.

During Cahill's youth a great deal of effort was being applied to the perfecting of electric generators (also called alternators or dynamos). Alternating current generators were known to produce current which changed its direction according to a pattern graphically represented by a sine wave.

The newly invented telephone operated on the principle that acoustic sounds (or vibrations in the air) could be converted into corresponding fluctuations in electrical flow by a microphone and then reconverted into sounds by a telephone receiver.

Cahill reasoned that the output from an alternator could be fed directly into a telephone receiver to produce an audible sine tone. The frequency of the tone could then be controlled by regulating the speed at which the shaft of the alternator turned. The outputs from many alternators turning at appropriate speeds could then be thrown onto the line by little switches operated by the keys of a keyboard adapted from an organ console.

With many, many more alternators and an incredibly elaborate switching arrangement, it would be possible to create the complete harmonic series for each fundamental and adapt the drawstops on the console to enable the performer to regulate the exact volume of each harmonic individually. It was a fairly simple matter to combine all of the various alternator outputs in a single line, thereby creating at the telephone receiver complex tones whose timbres were under complete control.

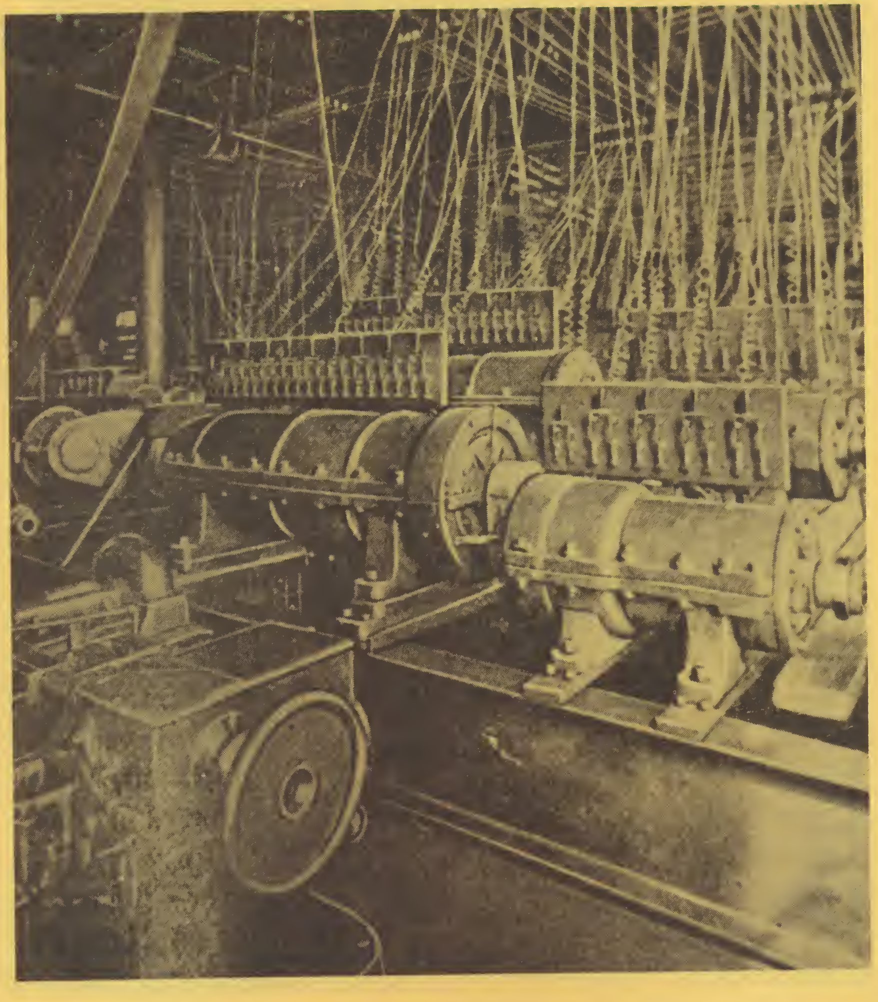
Compared to a vibrating string or air column, fluctuations in electrical current flow can be much more responsive. (Electricity has virtually no inertia.) In the late nineteenth century, with electricity accomplishing new marvels every day, Cahill's arrangement looked promising indeed.

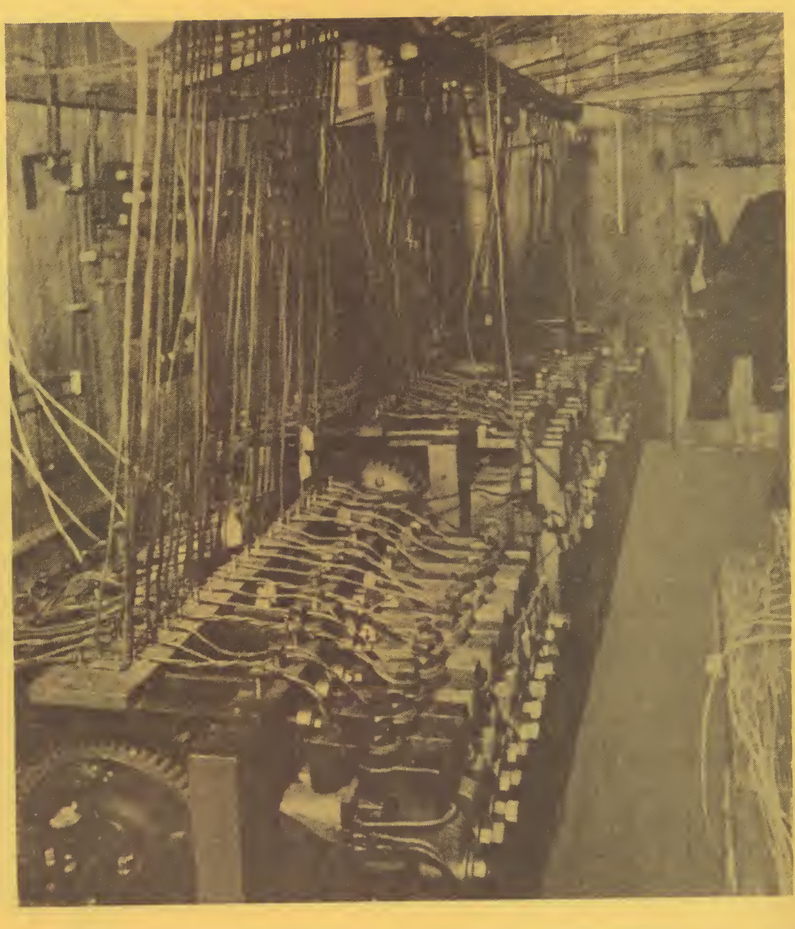
ON DISTRIBUTION

Very early in the history of the telephone there had been attempts to transmit a musical concert over the wires. This was done by merely holding the telephone transmitter up to the musical instruments. (The microphone, acting as a variable resistor, made little ripples in the direct current which could be translated back into sound by the receiver on the other end.) But amplifiers had not yet been invented, and the feeble signal generated in this manner was extremely limited in both frequency and dynamic range. Also, because of the weak signal, the interference caused by the inherent induction in the wires and the spikes (created, for instance, when people raised or lowered other phones), while not so disruptive to conversations, was found intolerable in music.

Cahill's machine produced the variations in the electrical current directly— he was not bound by the limitations of a microphone. And since each of his alternators was an electric generator capable of putting out 12 - 15 kilowatts — and he would have more than a hundred of them — there would be virtually no limitations on power and a vastly improved signal-to-noise ratio. (At peak power, he claimed to have millions of times the strength of the signal used in telephone communications.) He could hook up his machine to any number of telephone receivers or speakers. He could then have subscribers who paid to have music piped from a central station into their homes, night-clubs, restaurants or ballrooms.

On this plan he founded the New England Electric Music Company and obtained financial backing. In 1904 he made a successful trial transmission of music from his plant in Holyoke to New Haven (70 miles). A larger, improved machine was moved from Holyoke to New York City in 1906 to begin public service. It filled 30 boxcars, weighed 200 tons, and cost $200,000. He established "Telharmonic Hall" at 39th Street and Broadway with his alternators, transformers and switching devices in the basement and the console upstairs.*





* He states clearly in the patents that the performers should not only be in a separate room but should be acoustically isolated from the roar and clank of the apparatus. A speaker was placed next to the console, of course, so that the players heard exactly what the subscribers did.

PROGRAM *and* ANNOUNCEMENT

Telharmonic Hall

39th St. and Broadway
New York City

The first Central Plant of the New York Electric Music Company

O T CROSBY, PRES F C TODD, VICE-PRES C. M. PIHL, MANAGER

No. 1.

Public Entertainment Department
CARL HERBERT, *Manager*

MUSICAL STAFF

MR. HENRY W. GEIGER.
MR. HAROLD O. SMITH.
MR. CHRISTIAN SCHIOTT.
MR. O. SCHEDA.
MR. KARL W. SCHULZ. Ass't Musical Director

ELLIOTT SCHENCK, *Musical Director.*

Recitals and Demonstrations Daily

3.00, 4.45, 8.30 and 9.45 p. m.

Sundays, 8.30 and 9.45 p. m.

Public Service Information in the Business Offices

NOTE:—This PROGRAM will be changed constantly, many novelties being added currently.

MUSICAL PROGRAM

SELECTION 1	3.00 P.M.	RECITAL	Nocturne in E flat,	*Chopin*
	4.45 "	"	Solveg's Song,	*Grieg*
	8.30 "	"	Intermezzo, "Sizilietta,"	*Blon*
	9.45 "	"	Prelude in E minor,	*Chopin*
SELECTION 2	3.00 P.M.	RECITAL	Norwegian Folk Song,	*Ole Bull*
	4.45 "	"	First Meeting,	*Grieg*
	8.30 "	"	Second Waltz,	*Godard*
	9.45 "	"	Andantino,	*Lemare*
ILLUSTRATION ENGLISH HORN AND FLUTE 3	SELECTION, "William Tell,"			*Rossini*
VIOLIN ILLUSTRATION	3.00 P.M.	RECITAL	Nocturne in B flat,	*Field*
SELECTION 4	4.45 "	"	Intermezzo,	*Mascagni*
	8.30 "	"	Nocturne in B flat,	*Field*
	9.45 "	"	Romance,	*Sivori*
SELECTION 5	3.00 P.M.	RECITAL	Intermerzo,	*Macbeth*
	4.45 "	"	Intermezzo,	*Macbeth*
	8 30 "	"	Andante for 'Cello,	*Golterman*
	9.45 "	"	"Evening,"	*Schytte*
ARC LIGHT SELECTION	3.00 P.M.	RECITAL	Ave Maria,	*Bach–Gounod*
SELECTION 6	4.45 "	"	Ave Marla,	*Bach–Gounod*
	8.30 "	"	Traumerei,	*Schumann*
	9.45 "	"	Traumerei,	*Schumann*
SELECTION 7	3.00 P M.	RECITAL	Madrigal,	*Simonetti*
	4.45 "	"	Canzonetta,	*Godard*
	8.30 "	"	Love's Dream after the Ball,	*Czibulka*
	9.45 "	"	Stephanie Gavotte,	*Czibulka*
SELECTION 8	3.00 P.M.	RECITAL	'Cello Solo,	*Golterman*
	4.45 "	"	Waltz, "Loin du Bal,"	*Gillet*
	8.30 "	"	Minuet,	*Paderewski*
	9.45 "	"	The Letter of Manon,	*Gillet*
SELECTION 9	ORGAN POSTLUDE,			*Selected*

ON THE AVAILABLE INFORMATION

Cahill's machines were expensive. He was financed by the investments of industrialists and the sale of a certain amount of public stock. There were problems with the machine which could have jeopardized his financial status. It appears as though he carefully controlled the flow of information to his subscribers and the public.

There were apparently two periods when the machine was publicly exhibited. The first was 1903-4 (probably to enlist financial support), the second 1906-7, when he was ready (or almost ready) to solicit public subscribers for his services. During 1906-7, he gave several public concerts which were received by a unanimously ecstatic press quoting near-identical information about the machine, its possibilities and its future. (All the articles we know of are listed on page 35.)

This is in no way meant to imply that the telharmonium was not genuinely impressive. Ray Stannard Baker heard a concert in Holyoke in 1906. His comments below are typical of the reviews received.

A wire runs from the laboratory to the Hamilton Hotel, about a mile away, and the telephone receiver, fitted with a big paper horn, was placed in the ball-room at the top of the building. A switch near at hand turned on the music and regulated the tones either soft or loud, the musicians, of course, being located at the keyboard in their own small rooms at the laboratory, a mile away. I am not a musical critic, but of a few things any one may at once make sure. When the music began, it seemed to fill the entire room with singularly clear, sweet, perfect tones. Although expecting somehow to hear the whir of machinery, or the scraping sounds common to the phonograph, I was at first so much interested in the music itself that I did not once recall its source. Afterwards, I listened especially for some evidence of the noisy dynamos which I had just seen, but without distinguishing a single jarring sound; nor was there any hollowness or strangeness traceable to the telephone or its horn attachment. It was pure music, conveying musical emotion without interference or diversion. As one listens, the marvel grows upon him — the marvel and the possibilities which it suggests. The music apparently comes out of nothingness, no players to be seen, no instrument, nothing but two wires running out of the wall; and in hundreds of different places widely separated — the present machine can supply over one thousand subscribers — the same music may be heard at the same moment.

The first impression the music makes upon the listener is its singular difference from any music ever heard before; in the fullness, roundness, completeness, of its tones. And truly it is different and more perfect; but strangely enough, while it possesses ranges of tones all its own, it can be made to imitate closely other musical instruments: flute, oboe, bugle, French horn and 'cello best of all, the piano and violin not as yet so perfectly. Ask the players for fife music and they play Dixie for you with the squealing of the pipes deceptively perfect.

The one article which provides insights into the enterprise not found in the contemporary reports was written in 1924 (long after the company had failed) by Edwin Hall Pierce. Pierce had been employed by Cahill to perform on the telharmonium and to train others to do so.

ON THE IMITATING OF ORCHESTRAL INSTRUMENTS

It was perhaps natural to assume that the complete control over the harmonic series could lead to exact imitation of any existing instruments (not to mention the possibilities for creating new sounds). Much was tried, and apparently the attempts came closest to the woodwind family. Pierce reported: "We soon learned that the flute tone is very nearly a simple one; the clarinet tone has its third partial very prominent; the oboe tone has upper partials rather strong in proportion to the fundamental, etc." String instruments proved more problematic. Not only was it difficult to find the right harmonic content, but many reports noted a lack of the scratching of the bow and of a true flexibility.

But details were assumed to be within the realm of future developments, and there was talk of making an orchestra out of 12 - 20 dynamophones. Ray Stannard Baker offered the following:

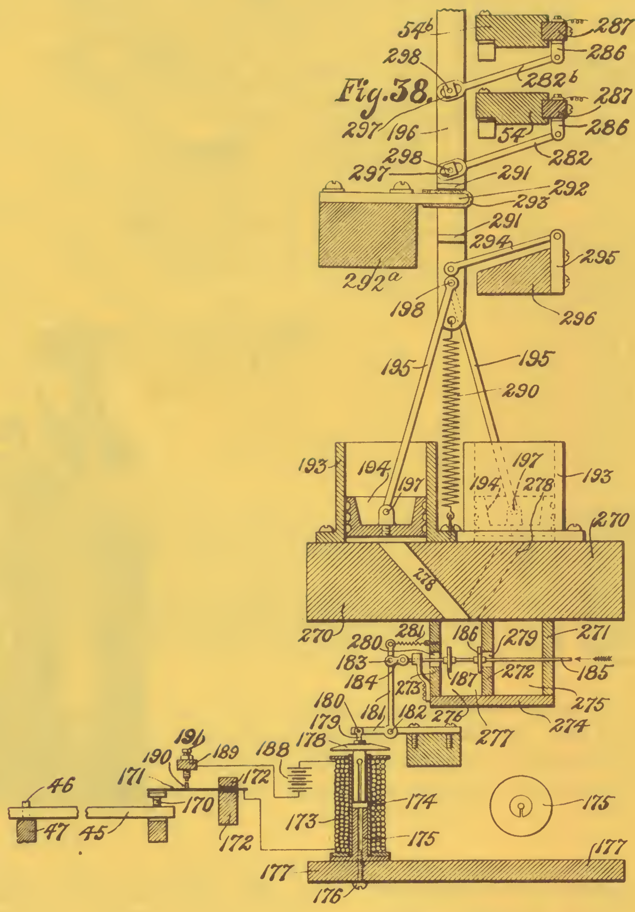
> But it would be absurd to say that the new instrument will even seriously interfere with the presentation of great music of any sort. It will rather add to the public interest in music and the appreciation of musical art. The automobile has not replaced the horse, and in an age of electric lights we still use gas and kerosene oil, not to mention candles.

The more immediate plans called for exploiting the machine's imitating capacity only for an occasional demonstration, the bulk of the performances to be of standard literature transcribed for the dynamophone more or less in the manner of piano transcriptions. (It apparently required two players to perform most everything.) The plan was to transmit four different programs, alternating at first, but eventually to be sent out simultaneously from four instruments over four sets of wires. The programs were to consist of 1) operatic music, 2) classical music, 3) sacred music, and 4) popular airs "which many people really enjoy whether they should or not" (Baker).

THE INDEPENDEN

Music by Wire

A new and very interesting instrument, the Telharmonium, is now attracting a good deal of public attention, and promises to place at the command of those desiring it better music than that commonly discoursed in hotels, restaurants and like places by union musicians, at less cost per "harmel"—a new unit compounded of harmony and melody, after the manner in which the technical literature of electricity has been enriched with a new nomenclature.



Part of the switching arrangement. The key (45) connects (190) the battery (188) to the relay (174) which pulls the levers (180 and 181) which open valve (186) that forces air up the channel (276) which pushes piston (197) and bar (196) upward. The bar closes switches (282), and the spring (290) pulls the bar down to open the switches when the relay is no longer energized.

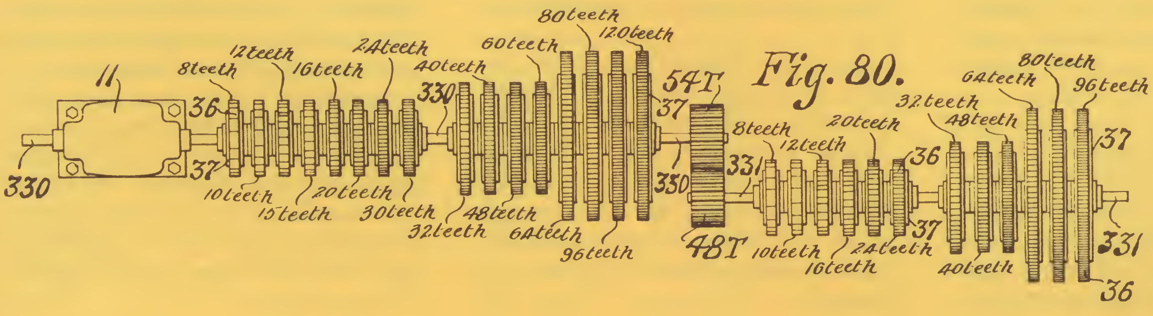
Cahill's patents on the telharmonium (or dynamophone) are:

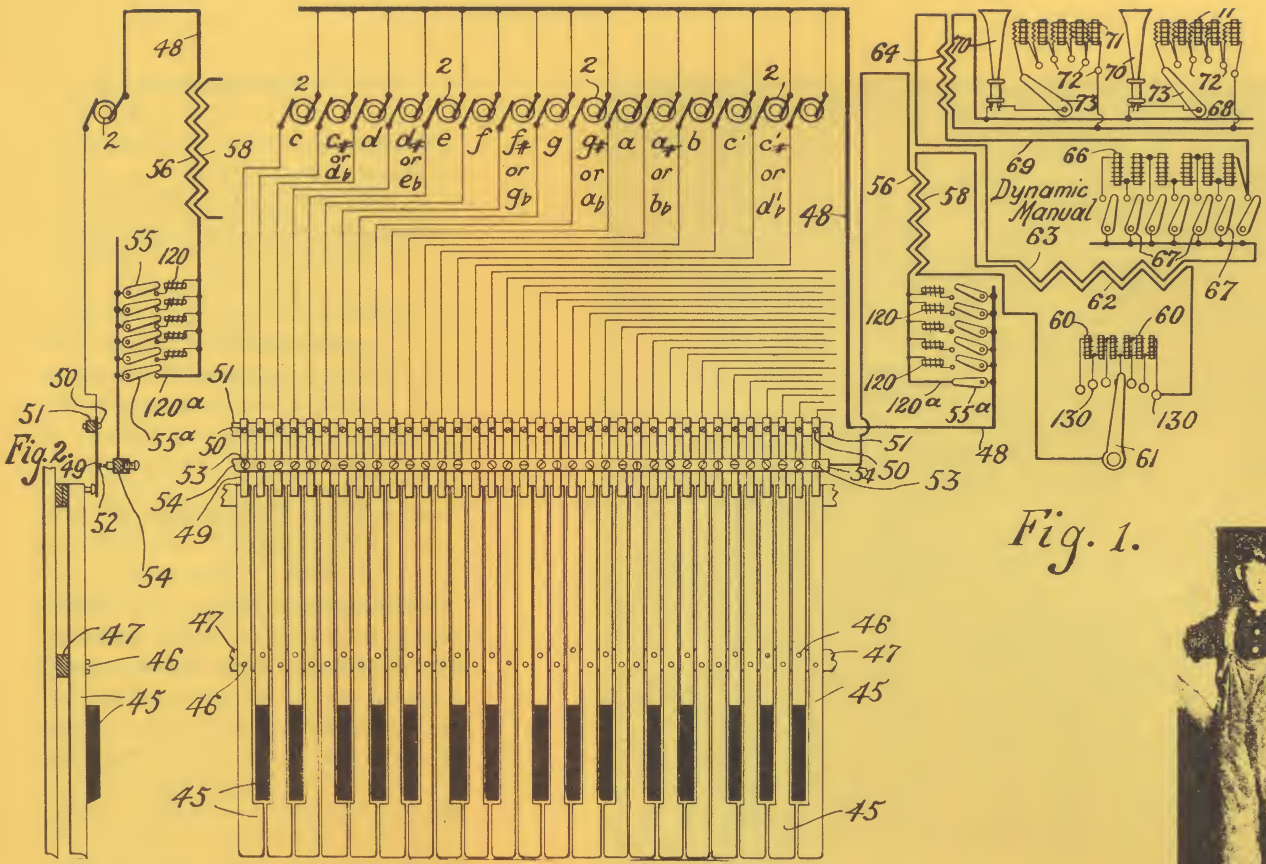
1. Patent Number 580,035; granted 1897 (55 pages)
2. Patent Number 1,107,261; granted 1914 (33 pages)
3. Patent Number 1,213,803; granted 1917 (45 pages)
4. Patent Number 1,213,804; granted 1917 (154 pages)
5. Patent Number 1,295,691; granted 1919 (141 pages)

(Many years separate the date filed from the date granted.)

When filing his patents Cahill found that 1) nothing like his idea had ever been tried before, and 2) he was not patenting an invention as such but a certain arrangement of already existing inventions for a specific purpose. His machines were frightfully complex, and his patents discuss many possible dispositions of devices for the purposes of creating and distributing music electrically.

Evidently the machine(s) he built were constantly being changed. What we describe in this article is what we believe to be his ultimate achievement but, particularly in relation to his "expression devices," the matter may be far from known. His first patent discusses a touch-sensitive keyboard, but subsequent patents deal with an action Cahill describes as more like that of an organ than a piano. In the last two patents he refers several times to three pending patents (filed in 1908-9) where he discussed additional devices for applying voltage to the line gradually (that is, creating nonrectangular envelopes). Apparently these three patents were never granted.





Cahill's basic system for generating music. The output from each alternator (2) is fed to the respective key switch (45) and out the common line to the coupling transformers (56, 58, 62, 63, 64). The signal passes through a set number of inductors (120, 60, 66) for loudness control. The secondary of the output transformer (64) feeds to the line going to the subscribers. A horn (70) and a loudness control (72) is at each subscriber station.

A pitch shaft.

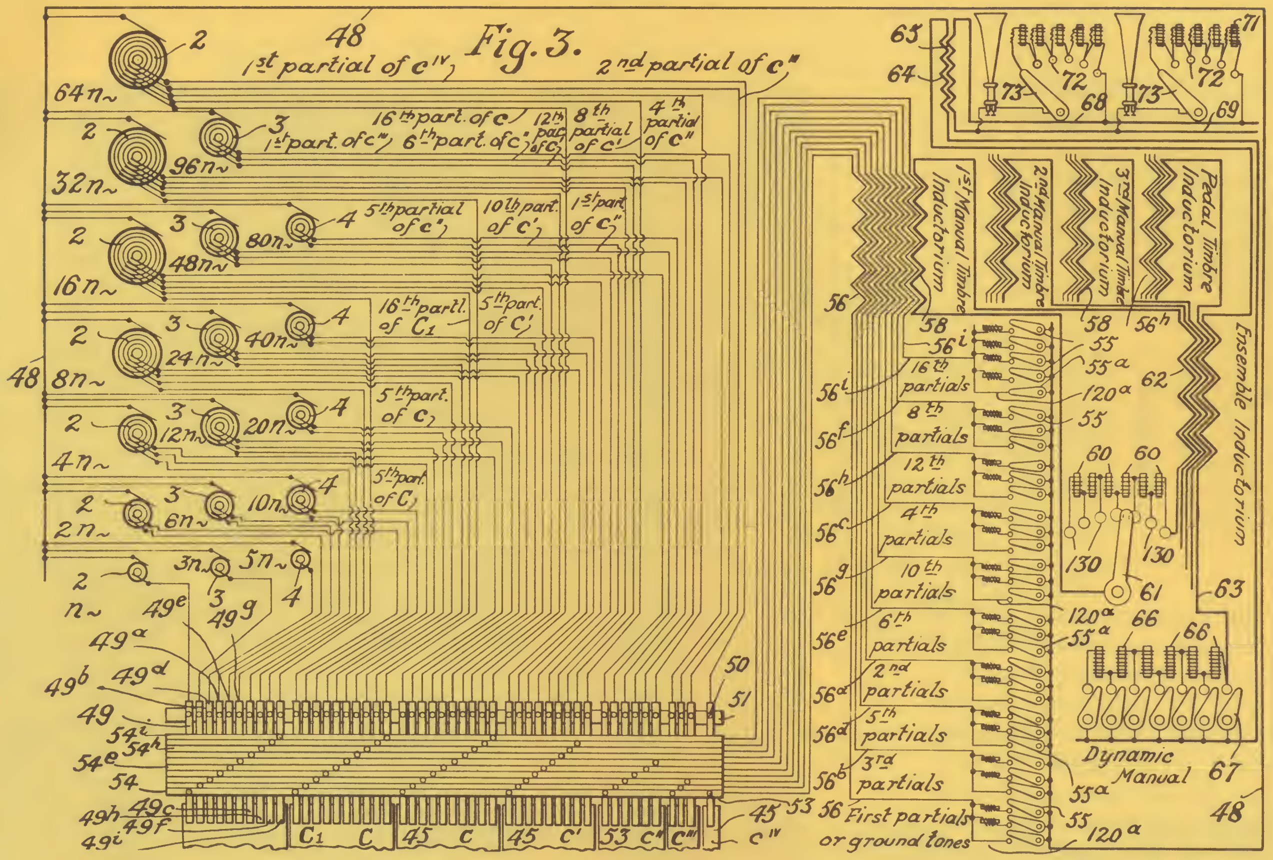
ON ALTERNATORS & INTONATION

The patents refer to the construction of twelve identical "pitch shafts," each shaft consisting of seven alternators producing seven octaves of a given pitch. The different octaves were produced on each shaft by doubling the number of magnetic poles in each consecutive alternator (see the picture). The single turning shaft meant that the seven alternators would have to produce exact multiples of the frequency of the bottom alternator, thus insuring perfect tuning. (Pierce reports that an octave sounded from two of these alternators did not sound like an octave at all, but as if the single bottom pitch had been enriched.)

The specific pitch produced by a pitch shaft was determined by the speed at which the shaft revolved, so that twelve identical pitch shafts turning at twelve different speeds could produce the complete chromatic scale over seven octaves (less one note). The differences in speed were ultimately achieved through an elaborate, all-encompassing, gearing mechanism, and all shafts were powered by a single electric motor. The speed of each shaft could be precisely determined by the number of teeth of the various gears. Again, the intonation was perfect. That is, if the motor ran too slowly (as was frequently the case), the entire instrument could be below pitch, but no part could be affected without affecting the whole — the frequency ratios were absolutely fixed. (Cahill proudly states that this sort of permanently fixed tuning probably had never before been achieved on any kind of instrument.)

A simple arrangement which connects the outputs of these pitch shafts to switches operated by the keys of a console keyboard is shown schematically in his figures 1 and 2. This would produce, of course, sine tones for each pitch. The full complement would involve 84 alternators (12 pitches x 7 octaves).

But Cahill was after complete control of the harmonic content of each pitch, and that made the problem much more complex. He could not, for instance, simply combine the outputs from his existing alternators at pitches CC, C, G, c, d, g, b^b and c′ to produce the first eight members of the harmonic series on CC, because the two G's, the E and the B^b would be out of tune. His twelve shafts were geared to produce equal tempered tuning — and that implies that all intervals save octaves are compromised. These mistuned intervals are acceptable in melodies and chords but were found to be frequently unacceptable as harmonics. (He could not have originally opted for another tuning system because all others would have required at least two alternators (at slightly different frequencies) for each pitch-name. This would have more than doubled the cost of the machine and, in any case, there is no tuning system which can simply do away with all compromises in intervallic relationships.)



Synthesis of a complex tone. Sine-wave harmonics from the proper alternators are fed to bus bars (54). Pressing a particular key (C in this case) connects each harmonic to a multicoil transformer (56, "inductorium") where they mix inductively. Each harmonic is attenuated to a desired level by the inductors in series with each winding (56a, b, etc.). The tap-switch inductors (60) regulate the amplitude of the mixing transformer output, as do the inductors near the loudspeakers (72, 73) at the subscriber's end of the line.

Cahill once said that 3-400 alternators would be necessary for a truly complete instrument. In his patents, he describes many less expensive solutions to the problem. Each solution is some compromise between cost and musical possibilities. Harmonics which were octave multiples of the fundamental were of course available from the same pitch shaft. Harmonics which were a fifth above the fundamental appeared to be the most critical. After one of his less expensive solutions he states:

> The approximate third, sixth and twelfth harmonics, furnished by the apparatus before described (although varying by only a little more than one one-thousandth part from the true third, sixth and twelfth harmonics), I find to be much inferior to the corresponding true harmonics — so much inferior, that they ought not, in general, to be substituted for them and can have, it seems to me, but a very limited and special use, depending on the genius of the musician.

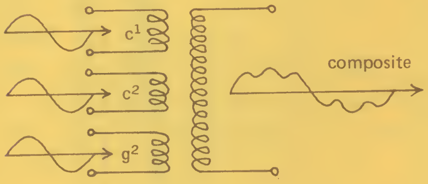
The arrangement he finally decided to use involved enlarging each of his twelve shafts to include two additional shafts geared together. Now, in addition to one shaft producing the seven octaves of C's, it also included another shaft producing six octaves of G's (at the exact numerical proportions appropriate for harmonics) and a third similar shaft for five octaves of E's. He thus had available from each "shaft" eighteen pitches corresponding to the perfectly-tuned fundamental (plus octave duplications), the third harmonic (plus octaves) and the fifth harmonic (plus octaves). He arranged the switching on the console so that nine draw-stops could individually control the volume of the harmonics numbered 2, 3, 4, 5, 6, 8, 10, 12 and 16. One could then preset each of the stops so that the timbre of a given keyboard was fixed in advance. That is, all second harmonics (on one stop) could be set for a given volume, all third harmonics (on another stop) to a different volume, and so on. The volume of the total output could be regulated by a foot pedal and/or a dynamic keyboard. (This is shown in his figure 3.)

There was also some provision made through cross-switching for the harmonic seventh. Pierce reports that the seventh, if its timbre was relatively pure, could be included in the final triad of a piece — it had no tendency to resolve.

Cahill reported his frequency range as 40-4,000 Hz. That would have given him a range of approximately the lowest E to the highest B on a piano. (The patents, though, usually begin discussions with an alternator set at C = 32 Hz.) The higher pitches did not have available a complete harmonic complement because Cahill found the extremely high harmonics harsh (and they rapidly approach inaudibility in any case). As for the lowest tones, he reports that he had experimented with and found useful those (triadic) harmonics up through the 64th partial. (The best acoustic recordings of the time reportedly had a maximum frequency response of 168-2,000 Hz.)

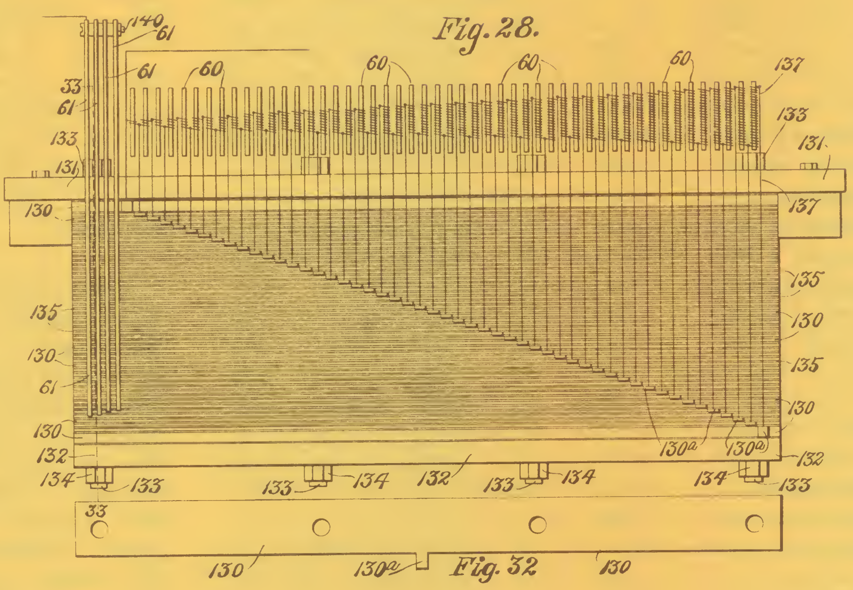
ON TONE MIXERS AND TONE PURIFIERS

The method of combining the individual sine waves was simply to put them through several primaries around a large secondary coil of a transformer.

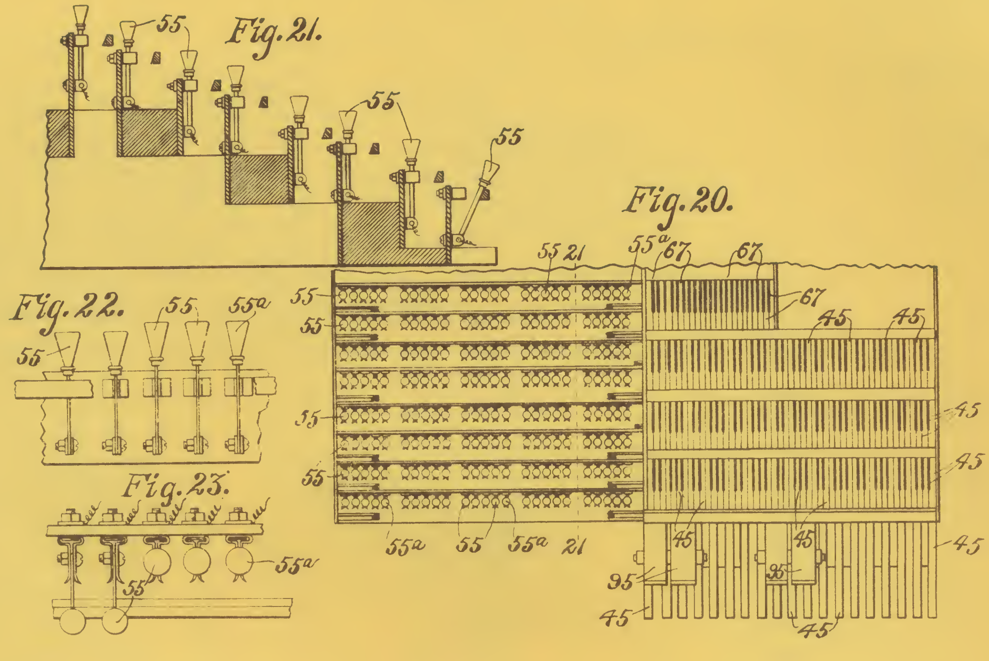


In Cahill's early machines, when he was dealing with rheotomes and apparently ill-tooled alternators, he found it necessary to put each tone through a specially designed coil to repress the impurities in its sine shape. Later he states that the impurities amounted to weak third and fifth harmonics which 1) were slightly repressed by the coils of the tone mixers and the induction in the transmission lines, and 2) were not objectionable in any case, their adding a little richness to tones otherwise utterly "pure."

A tone mixer.



Loudness control device, electrical connections. Used either as a foot control (swell pedal) or as a hand control, the bar at left moves toward the right disconnecting more and more coils in series with the signal. As each coil is disconnected, the inductive reactance is decreased, thereby attenuating the signal less. Four redundant bars (61) are used to assure contact on the copper horizontal bars at all times, thus preventing noise. A large number of coils are employed to provide for a gradual change of loudness.



The three lower manuals are for pitch control. The top abbreviated manual is for dynamic control. Each key is a discrete loudness control so that the player may change loudness abruptly. Cahill suggests that a weight may be placed on the desired loudness "thus leaving the performer's hand free for other purposes."

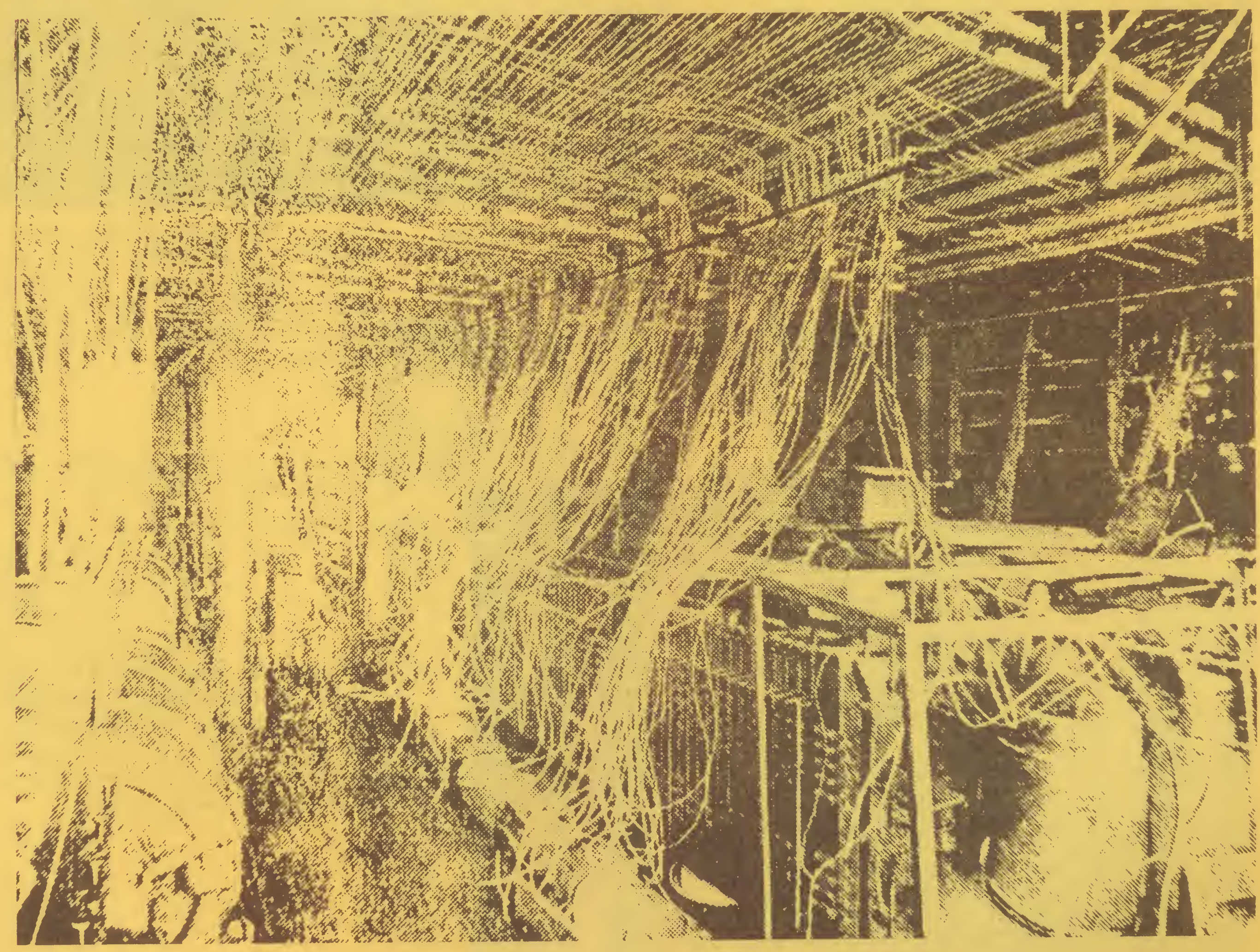


Fig. 3—Switchboard in Process of Erection.

Once the enlarged pitch shafts were decided upon, it was clear that there would be available three slightly different frequencies for each pitch-name (at least in the middle and upper registers). That is, the pitch shaft called C also had available six octaves of G's at exact 3-1 frequency ratios to the C's. These G's would be slightly higher than those produced on the well tempered G pitch shaft. And there also would have been the five octaves of G's pitched to the precise 5-1 ratios above the E^b pitch shaft. Although the patents give various gearing and switching possibilities only for equal temperament, Cahill, as it turns out, was quite taken with the idea of making his instrument capable of both equal- and just-tempered tuning systems.

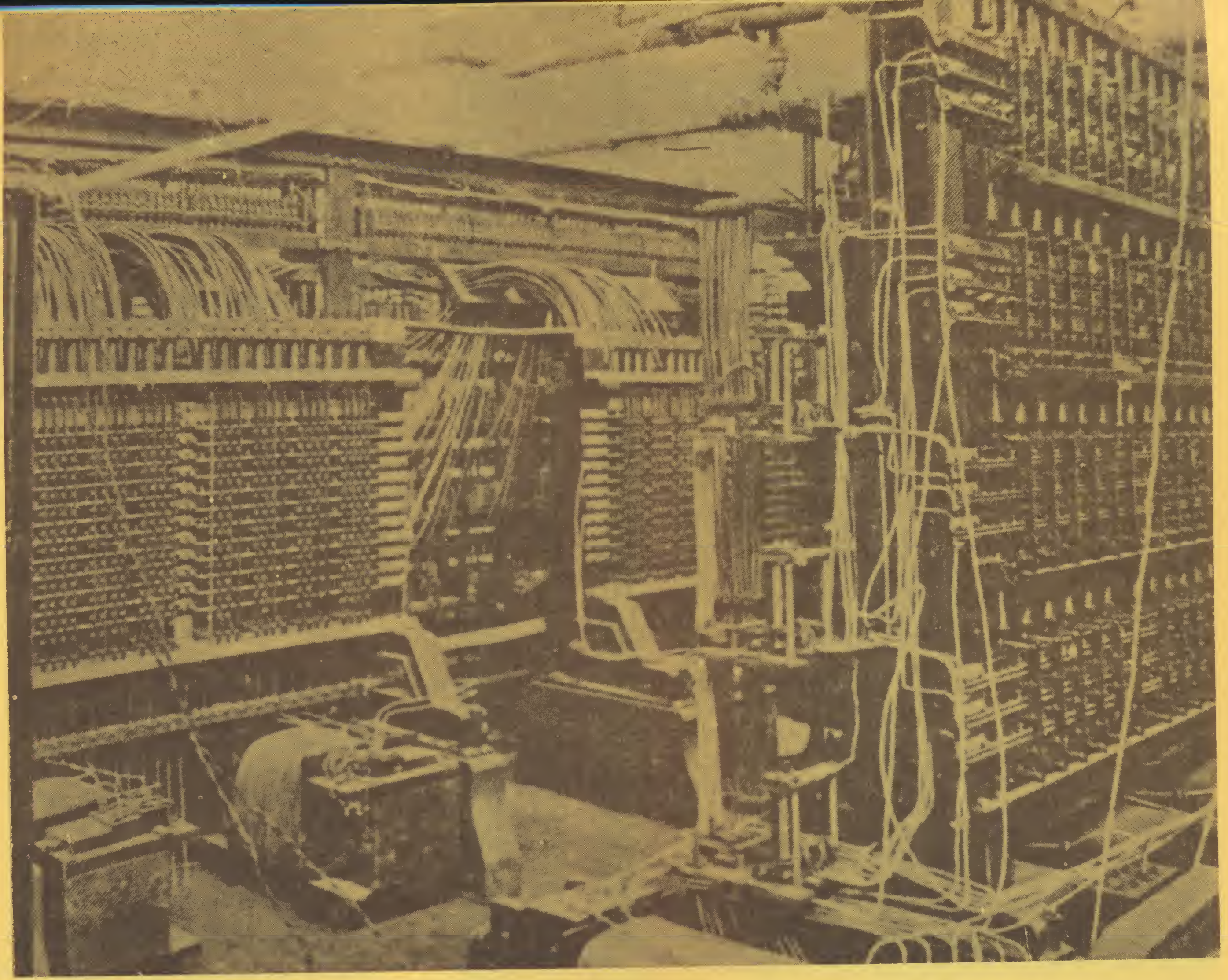
Even with equal temperament, each alternator had to be tapped separately for each of its possible functions (i.e., the alternator for c^3 could be a fundamental, a second harmonic for c^2, a third for c^1, etc., etc. -- each function requiring a separate wire). The amount of wires and switching devices to produce just intonation must have been immense, and there is hardly a hint that Cahill was even interested in it in the extant patents. (His largest machine was reported to have almost 2,000 switches.) There isn't much information available, but Pierce offers the following:

TWAIN AT THE TELHARMONIUM.—Last week Mark Twain visited the Cahill telharmonium plant, on upper Broadway, New York, and heard the music through a "singing arc" as well as by the telephone. He was greatly pleased and remarked: "The trouble about these beautiful novel things is that they interfere so with one's arrangements. Every time I see or hear a new wonder like this I have to postpone my death right off. I couldn't possibly leave the world until I have heard this again and again.

It became the present writer's task to devise a practical system of fingering on the new keyboard, which had 36 keys to the octave, and also to solve the problem of correctly indicating in some simple way the manner in which music was to be rendered in just intonation, in order that the several new players whom he taught should be able to use the keyboard properly. He decided to consider ordinary musical notation as representing the "equal temperament," and to add special signs to indicate those modifications which were needful to bring about "just intonation." As is well known to piano and organ tuners, in the tempered scale all major thirds are (and must be) too sharp; all perfect fifths too flat. The note A, for instance, when it forms the third of the triad of F major, is too sharp in the tempered scale, but when it forms the fifth of the triad of D major, is too flat, in the tempered scale. The error in the perfect fifth, however, is very slight, and in accordance with the inventor's design, it was ignored for the sake of simplicity, and attention directed more to the problem of the "third." (This decision was not arrived at arbitrarily: Dr. Cahill built *another*, but somewhat smaller instrument of the same sort in which provision existed for absolutely perfect fifths as well as thirds, and the improvement in the effect of chords was so slight as to be noticeable only with the most attentive and minute comparison.)

My first efforts, then, were with a hymn-tune of "chorale" character: I went through it marking every "third of a major chord" with a grave accent, to indicate that it was to be slightly lowered. With minor chords, I lowered the "first" and "fifth," letting the "third" stand. On the very ingeniously contrived keyboard, it was possible to follow these indications without undue difficulty.

Pierce also states that the young pianists he trained disliked just intonation for everything but the most Palestrina-like material (a fact which apparently offended Cahill). Pierce grew to agree with the young pianists.



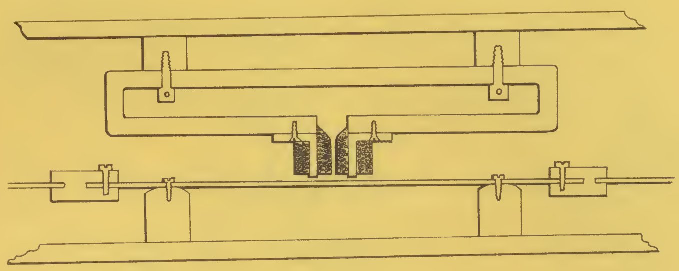
THE TELHARMONIUM: ELECTRICITY'S ALLIANCE WITH MUSIC.

BY THOMAS COMMERFORD MARTIN.

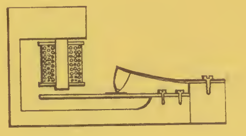
IN the new art of telharmony we have the latest gift of electricity to civilization, an art which, while abolishing every musical instrument, from the jew's-harp to the 'cello, gives everybody cheaply, and everywhere, more music than they ever had before. There are so many fundamental and revolutionary ideas embodied in the invention that it will be a long time before we grasp or grow accustomed to them all; and only one or two can now be accentuated. Electricity has been the greatest centralizing, unifying force these hundred years, and the "tie that binds" is distinctively made of wire.

PRECURSORS OF THE TELHARMONIUM

by Thomas L. Rhea



Patent Drawing for Ernst Lorenz's 1885 "Elektrisches Musikinstrument"



From the composer's viewpoint, the history of electronic music, *per se*, begins with the advent of magnetic tape manipulation. However, experimentation with electrical *means* of producing musical sounds predates the arrival of the tape medium by more than a century.

The earliest use of electricity in music was in motordriven acoustical instruments such as J. B. Delaborde's "Electric Harpsichord" (1761) and Hipp's "Electromechanical Piano" (1867). This kind of device, which used electricity solely as a motive power, could not be included in a discussion of "electronic musical instruments," defined as devices in which periodic electric currents are generated and controlled, and translated into sound. I have adopted such a definition for this discussion.

Many of the first discoveries in electrical music came about accidentally, as the by-product of an experiment concerning the general behavior of electricity. This was the case in the production of "galvanic music" by Dr. C. G. Page of Salem, Massachusetts, in 1837. Page was experimenting with several horse-shoe magnets, and a coil attached to a battery. He noticed that when one or both poles of the magnet were placed by the coil, a distinct ringing was heard in the magnet when connections to the battery were either broken or made. Page was evidently not aware of the elementary features of coils, for he suspected that the ringing was caused by reverberation from the loud snap made when the connection was broken. To test his theory, he removed the battery to a considerable distance and repeated the experiment. The results were, of course, identical. Page had inadvertently discovered the principle of the electronic tuning fork.

In 1839, Neef designed a system in which a spring and a magnetized bar interacted to cause vibrations in a steel armature. In 1885, Lorenz patented an instrument using a similar design.

Lorenz's instrument embodied two kinds of devices. The first was a circuit interrupter which served to create periodic electrical currents. The circuit interrupter used an electromagnet to attract a metallic bar. A small clapper on a spring mounted above the bar then broke the circuit and forced the bar to return to its original position. The electrical vibrations produced were used to drive an electromagnet in the second device, a resonator. This electromagnet was placed adjacent to a metallic membrane which was connected to resonating boards, translating vibrations into sound. The instrument consisted of a complete set of the current interrupters and a resonating device. Lorenz indicated that "suitable resistances" could be added to the circuit to give control over the "growing" and "dying" of the tones. He suggested that pedals might be used to control this rudimentary system of envelope control.

In 1899, William Duddell, an English physicist, discovered that the carbon arc lamp used for lighting could be made to produce musical notes. The "Singing Arc" consisted of a direct current arc and a shunt, or secondary circuit in parallel, consisting of a coil and a capacitor. The oscillations produced in the secondary circuit reacted on the arc, causing regular interruptions in the discharge, creating a musical note. The pitch and intensity of the note produced depend upon capacity, self-induction, and resistance in the secondary circuit, and the potential difference of the arc terminals. High potentials gave clear notes, and the pitch produced from combinations of self-inductions and capacities could be approximated by the formula ($2\pi\sqrt{LC}$).

Duddell built a keyboard which controlled the characteristics of the secondary circuit, causing the arc to produce musical notes.

When Duddell played his "Singing Arc" before the London Institution of Electrical Engineers, arc lights in two close-by laboratories also played tunes during the time of the demonstration. At first, no explanation could be given, but it was later determined that the arc lights were on the same circuit with Duddell's musical arc. When the "Singing Arc" was played, it produced variations in the main line, thus accounting for the strange behavior of the arc lights. The possibility that several arcs could be played at a distance from one keyboard led to speculation that concerts might be given in conjunction with lighting service — ("brilliant performances?!"). Duddell, however, did not pursue the matter, abandoning his application for British patent.

Even though the "Singing Arc" did not become a popular musical instrument, it was important historically, for it was probably the first totally electric instrument.

Against the background of these early experiments with electricity and music, the electromagnetic musical system designed and built by the American inventor Thaddeus Cahill, stands as the *tour de force* of early electrical musical instrument construction.

ON PROBLEMS

Cahill ended his last two patents with a discussion of problems which he had not been able to completely overcome. The three he considered most severe he called diaphragm crack, shouting, and robbing.

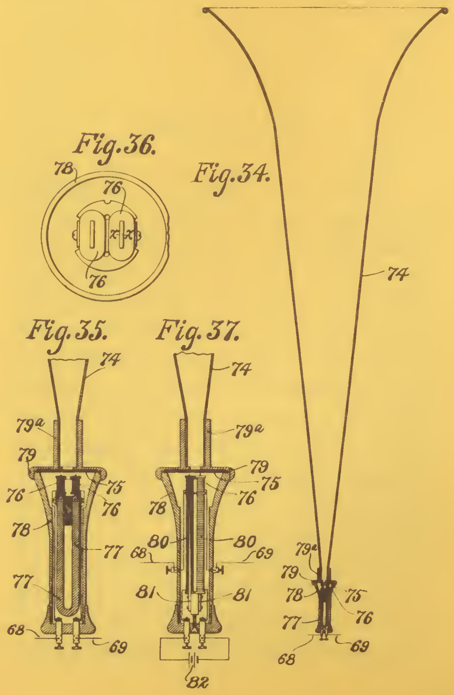
Diaphragm crack was a jarring noise which occurred when current was introduced or withdrawn from the line. In legato playing (assuming the performer had mastered the unique touch of the instrument) the current was continuously on the line and there was a problem only at beginnings and endings (which could have been minimized with the swell pedal). But in staccato playing the problem was apparently severe. Cahill's final solution is a bit puzzling to us. He states that

> . . . breaking each circuit in two places seemed to give a better musical effect; probably by reason of the fact that by this means each circuit was normally disconnected from its common return when the circuit was in action . . . I afterward found that by breaking the circuit in three places, a still better effect was produced . . . By these means, as I understand it, the electrostatic effect was still further reduced.

The problem of shouting was primarily a result of the resonance points of his speakers. Certain tones would be markedly accented. It might be assumed that he could have simply reduced the volume level for those pitches which were at the critical frequencies, but the solution was not that simple. Cahill's ultimate statement on the subject is as follows:

> Using receivers that are as nearly as possible alike, keeping them at substantially the same temperature (say about 70 degrees Fahrenheit), running the alternators at a constant speed, regulating the voltage of each alternator by means of rheostats and regulating the relative strengths of the different numbers of turns or coils to each winding, as before described by doing *all* these things, the difficulties resulting from shouting can be eliminated or greatly reduced (italics ours).

The problem called robbing had several problematic manifestations. Each alternator had a separate wire leading from it for each of its possible functions. These wires led into the appropriate draw-stops which acted as volume controls. But the voltage produced by the alternator in any given wire decreased if the alternator was being used in more than one capacity simultaneously. That is, if c^3 were to be both a fundamental and the third harmonic of f^1, its volume in both those capacities would be suddenly less than when it was used for only one function. (Another aspect of robbing is mentioned in the final citation from Pierce.)



Telharmony

ON FAILURE

We have not been able to determine just when the company failed. Reports differ. Several name a specific year — either 1906, 1907 or 1909. Most claim the reason to be the disruption of telephone conversations. (One claims that J. P. Morgan was personally implicated in the company's demise after a phone call of his own was disturbed.) But as late as 1911 the Holyoke Transcript-Telegram reported: "All the fixtures and machinery belonging to the Cahill Telharmonium Company were placed on 10 flat cars this morning and will be shipped to New York where Mr. Cahill has already opened a large factory." This paper later (1934) attributed the company's failure to the rapid development of the radio.

Perhaps Cahill would have preferred any of the above reports to that given by E. H. Pierce in 1924:

This article properly ends here, yet I believe that it will better satisfy the reader if a few words be added explaining the reasons for the ultimate failure of this wonderful, and in many respects beautiful, instrument. It was not because of any error in judgment in the matter of a system of tuning, for the instrument offered opportunities for the use of the tempered scale, and in fact (as we have narrated) came to be so treated, but it had several weaknesses, which I will enumerate.

First; owing to financial considerations, it was put into actual practical use before it was sufficiently perfected, and also before any of the players, notwithstanding the greatest zeal and diligence, had been able to conquer all its technical difficulties.

Second; under these conditions, the players were obliged to render a varied daily program to a most exacting public, with scarcely any opportunity for sufficient undisturbed practice. Quality naturally suffered.

Third; in order to support the great expense of the undertaking, it was necessary to have a very numerous body of subscribers: patronage was at first very prompt and encouraging, but vexatious delays were met with in running the necessary wires, in various directions, owing to both mechanical and legal difficulties, and many lost interest and cancelled their orders. Consequently only a small percentage of the hoped-for income became available, and the enterprise finally underwent failure.

In regard to the instrument not being in all respects perfected, the following were the most outstanding defects.

First; *owing to having but eight of the twelve "shafts" originally intended by the maker,** there were four keys (with their relative minors) in which it was impossible to play. Although this left still a wide range of modulation available, any musician will realize that it constituted a very serious drawback.

Second; owing to certain electrical complications too technical to explain here, the instrument was not fitted to the rendering of massive harmony. It was at its best in the use of two-voice and three-voice harmony, which is, of course, not in accordance with the genius of modern music. If, to a chord of three voices, another voice or two was added, the total strength of the chord became not greater, but *less* than before — a most vexatious and anomalous state of affairs.

Third; owing to certain electrical conditions, when a staccato touch was used, the staccato effect was apt to result in an exaggerated caricature, resembling blows from a tack-hammer. This defect the inventor succeeded in overcoming by a very ingenious device later on, but not until many hearers had become prejudiced against the instrument.

Fourth; although it was possible to produce many beautiful and varied tone-colors, it was impossible to use more than any two of them at once. This limited the opportunity for simulating orchestral effects.

Fifth; the well-known "growling" effect of chords closely grouped in the bass was greatly *exaggerated* in this instrument, so that harmonies which would have been perfectly agreeable for the piano, organ or string quartet, sometimes needed to be completely redistributed for this instrument. This would not have been an insurmountable obstacle, but was a matter which properly demanded longer specialized study than our working conditions permitted.

Lastly, in spite of the variety of tone-color available, the instrument itself had its own special character which pervaded everything, and which in time grew highly irritating to the nerves. All the musical staff agreed in admitting this to each other, though careful not to express their views to the public, nor to members of the company. Personally, I am positive that subscribers would have soon tired of it for this very reason, as people once tired of the "glass harmonica" which was a lively fad in the days of Benjamin Franklin, but which exhibited this same unfortunate characteristic.

* The italics at this point are ours, and it should be noted that, despite the fact that only 144 alternators (8 shafts x 18 pitches) out of a projected 216 were built, a complete chromatic scale was available on the instrument. The missing alternators meant that there were limitations on the harmonics available and some compromises in pitch for four (probably black) notes.

ON CAHILL'S INFLUENCE

Cahill's machine incorporated many of the essential features of subsequent electronic instruments. He had electrically-generated pitches (alternators), filters (tone purifiers), envelope control (a touch-sensitive keyboard), timbre control (through additive synthesis) and speakers (horns he built to attach to telephone receivers).

In the same year as Cahill's first grand showing (1906) Lee deForest invented the audion (now called the triode). By 1915, Bell laboratories had perfected the vacuum tube amplifier to the point where it made possible transcontinental telephone service. During the First World War a tremendous amount of money was poured into research, development and production of tubes and amplifiers. After the war they were relatively inexpensive and in ready supply. The Hammond Organ Company could then build a reasonably priced home model of the telharmonium which, although it sometimes lacked the exactness of Cahill's harmonic ratios, was far simpler and in most respects far more flexible. Several electronic organ companies came to life after the war, probably all owing something to Cahill.*

As to how much effect Cahill specifically had on later attempts to build synthesizers which could truly imitate acoustical instruments, we don't know. At any rate, he was the first serious worker in the field.

Cahill's influence on musicians was apparently nil. Neither his machine, of course, nor anything like it was available to composers before the end of the war. Again, there is some reason to believe that it would have appealed to some. There is a well-known reference to the telharmonium in Busoni's *Sketch for a New Esthetic of Music* (1907). (He learned of it through Baker's article in McClure's Magazine.) Busoni at the time was decrying formalism, systems, and the limitations of the concepts of consonance and dissonance. He was investigating alternative scales and talking about the essence of music as being "sonorous air." He considered Cahill's instrument as a possible deliverer from an impasse reached by instrumental music.

* As to influences in fields other than music, we have been told that Cahill's bout with the phone company spurred the development of multiplex telephone transmissions. (?) (The whole episode with Bell Telephone seems a bit mysterious to us — we haven't been able to get any information out of the Bell company. Also, Cahill's version of an electric typewriter enabled a girl to type 200 words per minute (?) according to the Holyoke Transcript-Telegram. But it didn't earn him so much as a mention in books on the history of the typewriter.

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A BASIC DESCRIPTION OF INDUCTIVE DEVICES RELATING TO THE TELHARMONIUM

Magnetism and electricity had been known as separate entities for centuries, but it was the discovery of their interaction which precipitated the electric age. There were perhaps two crucial events. The first, Volta's invention of the battery in 1800, made continuously flowing electricity available (as opposed to the instantaneous sparks generated by the Leyden jar.) The second event occurred in 1819 when Oerstad, during the course of a physics lecture, placed a current-carrying wire down on top of a compass. He noticed that the compass needle moved to a position perpendicular to the wire. He reversed the direction of electrical flow and found that the needle moved 180°. He published his observations and much experimentation followed.

INDUCTION, n. *Elect.*, *Magnetism.* a. the process by which a body having electrical or magnetic properties calls forth similar properties in a neighboring body without direct contact, as, (1) the process by which the relative motion of a wire and magnetic field produces an electromotive force in the wire; (2) the process by which a changing current in a circuit produces an electromotive force in the same or a neighboring circuit. b. a tendency of electrical currents to resist change.

Electromagnet. Magnets are considered to generate fields which are zones of magnetic influence (see figure 1). From the discovery of Oerstad it followed that the flow of electricity also created a magnetic field – electric current could interact with magnetism. It was found that making a coil out of the current-carrying wire increased the intensity of the field, and curling the wire around an iron bar could create a magnet of unprecedented strength. When the current was withdrawn, the bar returned to a magnetically neutral state. By 1831, Henry, using insulated wire to get the maximum number of coils per inch, made an electromagnet which could lift a ton of iron.

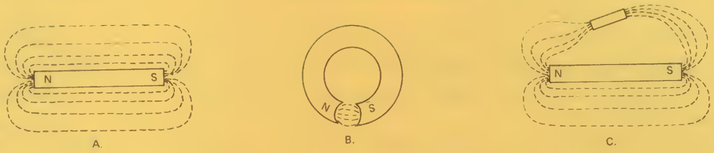


Figure 1. Some classical shapes of magnetic fields. The field is most intense in B. There is no known insulator against magnetic fields, but they can be bent by inserting a good magnetic conductor such as soft iron near their path (as in C.)

Telegraph. Henry also devised a system for sending messages by mounting an iron bar on a spring near the end of an electromagnet. When a switch closed the circuit, the bar struck the magnet making a clicking sound. When the circuit was opened, the spring returned the bar. Henry helped Morse perfect the system and by 1844 Boston and New York were connected by telegraph.

Relay. An obstacle to sending messages over great distances was the fact that the electrical power from the batteries would not travel very far. (The resistance of long wires removes considerable energy from the system.) Henry overcame this problem as follows. He stretched the original circuit to its maximum distance – until it barely had the power to attract the iron bar. Then the bar itself was made to operate as a switch, closing a different circuit having a new power supply. This arrangement could be repeated indefinitely, with all of the switches acting in sympathy with one another almost simultaneously.

The principle of the relay enabled Cahill to have comparatively delicate switches connected to his keyboard which could then activate large, high-powered devices further along the line.

Alternator. If electrical flow can be used to induce magnetic properties, magnetic fields can also be used to create electricity. It was soon found that jerking a wire through a magnetic field would produce a little burst of electricity in the wire. In 1831, Faraday found a way of creating continuously flowing electricity by spinning a copper disk between the poles of a horseshoe magnet. It took fifty years to work out the details, but Faraday's principle showed that tremendous electrical power could be obtained at the expense of creating a circular motion—and the technology of obtaining a circular motion from steam-engines and water-wheels was already well established. (A battery generates electricity by a comparatively feeble and constantly self-depleting chemical action.) Some principles involved in electric generators are shown in figures 2, 3 and 4.

Transformer. While Faraday was working to develop his electric generator, he discovered a principle which was to develop into the transformer (see figure 5). A transformer frequently involves two or more coils of insulated wire wound around a good magnetic conductor called a core. As alternating current flows through one coil (called the primary) the core becomes a magnet. As the sine wave of AC intensity moves from zero to maximum, the magnet becomes stronger and its field expands. As the AC moves back to zero the opposite happens and the magnetic field contracts. The changing magnetic field thus flows over the other coil (called the secondary) generating a sympathetic electrical flow in it.*

* Direct current also creates a surrounding field but, while the current is on, the field is stationary. Since it is not the field itself which produces the electricity, but the relative motion between the field and the wire, direct current will not pass through an inductive coupling device (except for little bursts of current produced at the instants when the DC is turned on or off).

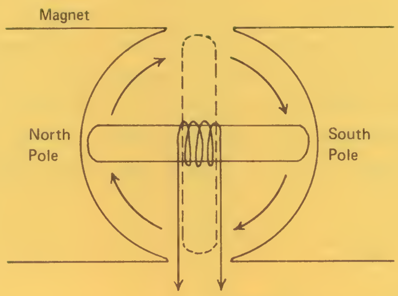
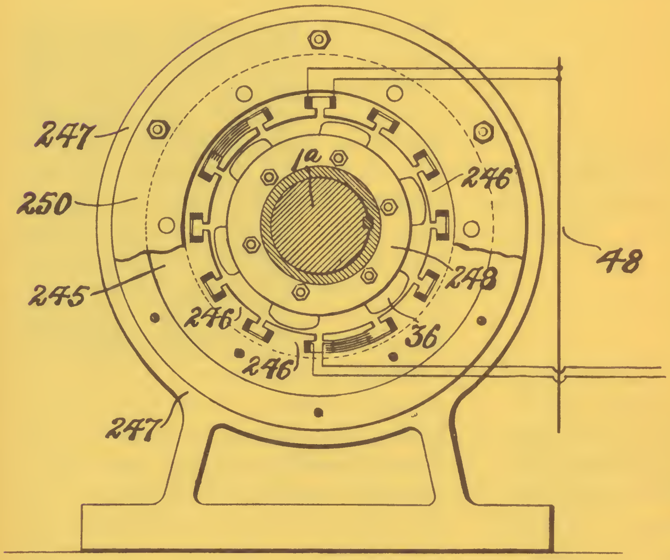


Figure 2. A simple electric generator. When the rotating bar is in the position shown by the dotted line, the influence of the magnetic poles is equalized, the bar has no magnetic properties, and no current is generated in the wire around the bar. As the bar moves to the position shown by the continuous line, it moves through a stronger and stronger magnetic field, it becomes a more and more powerful magnet with its own expanding magnetic field. As the bar passes this point, it becomes a weaker magnet again and its field contracts. The coil of wire around the bar is thus subjected to a constantly changing magnetic field, which produces electrical flow in the wire. The electricity is tapped by an arrangement of slip-rings and results in the pattern of intensity shown in figure 3.



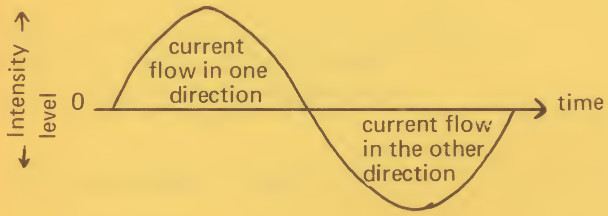


Figure 3. The standard graphic representation of alternating current flow. A sine wave. (The term *wave* can be misleading; the diagram is not meant to imply any up and down motion.)

Figure 4.
A schematic of an alternator from Cahill's last patent. This shows some of the hundreds of variations of the basic concept which have been applied. Among other things, here the number of poles and bars has been increased to increase the frequency of the resulting sine waves.

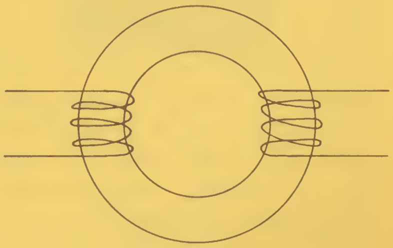


Figure 5. Faraday's coils wound around an iron loop. A transformer.

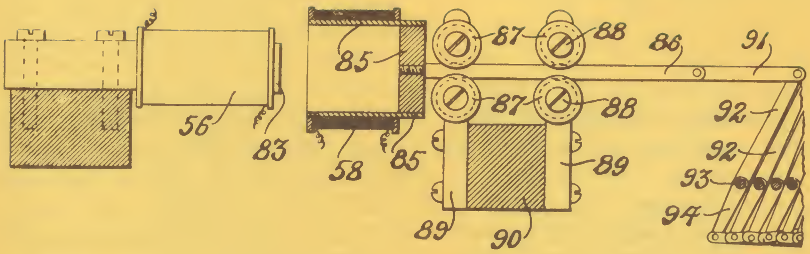


Figure 6. A volume control. The primary coil (56) carries a signal of a given strength. This is then inductively transferred to another circuit by coil 85. In the position shown, there is virtually no transfer. As coil 85 is moved to surround coil 56, more and more of the field produced by coil 56 cuts across coil 85 — the signal in coil 85 becomes stronger.

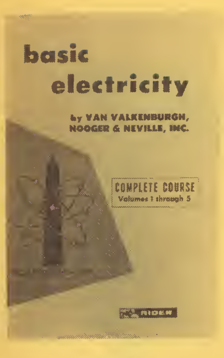
Figure 7. Impure sine waves.

Transformers are wonderous things. They can be upwards of 97% efficient in transferring power from one circuit to another and are crucial to the distribution and practical use of electricity primarily because of their ability to transform the voltage/current relationship in the process. But again, innumerable variations of the basic concept are possible. Cahill's tone mixer is shown schematically on page 24. There, several primaries are used to combine in a single secondary the instantaneous sums of electrical intensity in each of the primaries. Another use of inductive coupling used by Cahill is shown in figure 6.

Volume control. When alternating current is impressed through the primary of a transformer, the expanding and contracting magnetic field which cuts across the coils of the secondary coil also cuts across the coils of the primary itself. This creates an electrical voltage which opposes the incoming current. This sort of backpressure is called inductive reactance. Cahill frequently used this property of coils to regulate volume. Modern usage tends, for instance, to place a variable resistor in the amplifier circuit to control the amount of current reaching the speaker. The resistor takes some energy out of the system by converting it into heat and dissipating it into the air. Cahill, by placing five differently constructed coils on a switch near the speaker, accomplished a similar effect—he created five discrete levels of current which could be allowed to reach the speaker. But coils are essentially energy storing devices, not energy dissipating devices. The backpressure prevents some current from entering the line, but little energy is used up in the process.*

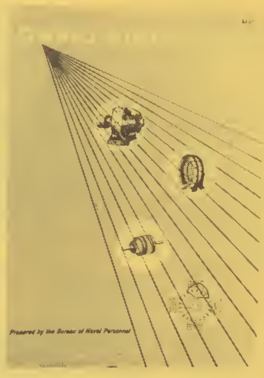
Tone purifier. Inductive reactance is a term used for measuring what is considered to be the natural tendency of current to resist change. Many factors influence the inductive reactance of a given coil: the number of turns of wire, the diameter of the coil, whether or not a metal core is inserted down the center of the coil, etc. But, regardless of the construction of the coil, the greater the speed of change in the current flow, the more the coil will impede that flow. Inductive reactance is frequency-dependent. That is, the faster the field cuts the coils, the more powerful the generated backpressure becomes. Cahill used this property in his tone purifiers. For example, the sine waves drawn in figure 7 have conspicuous impurities. If one imagines the horizontal line as a steady flow of time, it can be seen that the impurities represent more sudden changes in intensity than the rate of change represented by the rest of the wave. The rule is: the faster the rate of change, the greater the impedance. Therefore, passing the above patterns of intensity through an appropriately constructed coil (built so as to have minimum impedance to the sine wave itself) would have the effect of ironing out the impurities.

Cross talk. Inductive coupling is possible because of electromagnetic fields which always accompany the flow of electricity. These fields theoretically stretch out to infinity, but they become weaker and weaker as they distance themselves from the source. Shaping the wire into coils has the effect of heightening the intensity of the fields, but straight, uncoiled wires are also affected (only less so). Thus Cahill's powerful alternating current produced a changing forcefield around his wire for the entire length of the circuit. Even after Cahill had built his own independent wiring system, if his wire came near enough to a telephone wire so that his field intersected the field of the phone wire while both fields were of sufficient intensity, his music could have appeared on the telephone circuit without actually being connected to that circuit.

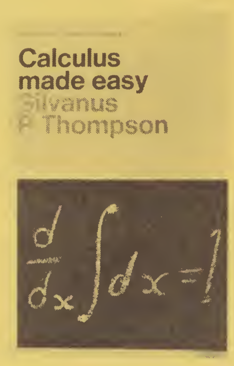


This was the beginning text for the Navy courses in electricity from 1953–60. It is the easiest exposition of the subject we have ever seen. It bypasses most of the mathematics, contains many pictures, and deals with basic definitions of electricity, magnetism, circuits, meters, Ohm's law, Kirchoff's laws, resistance, capacitance, inductance, transformers, generators and motors. Available as one hard-bound or five soft-bound books ($13.50) from: Hayden Book Company, Inc., 116 West 14th Street, New York, N.Y. 10011.

Developed by the Navy in 1960, it covers the same ground as the above but includes the requisite mathematics. It also has units on soldering, magnetic amplifiers, synchros and servomechanisms, schematics and safety precautions. $3.00 from: Dover Publications, Inc., 180 Varick Street, New York, N.Y. 10014.

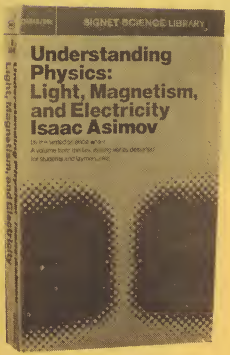


This is a beautifully clear book. It doesn't deal with calculus but reviews simple equation-solving, trigonometric functions, vectors, logarithms, etc. $9.95 from: McGraw-Hill Book Company, Princeton Road, Hightstown, New Jersey 08520.

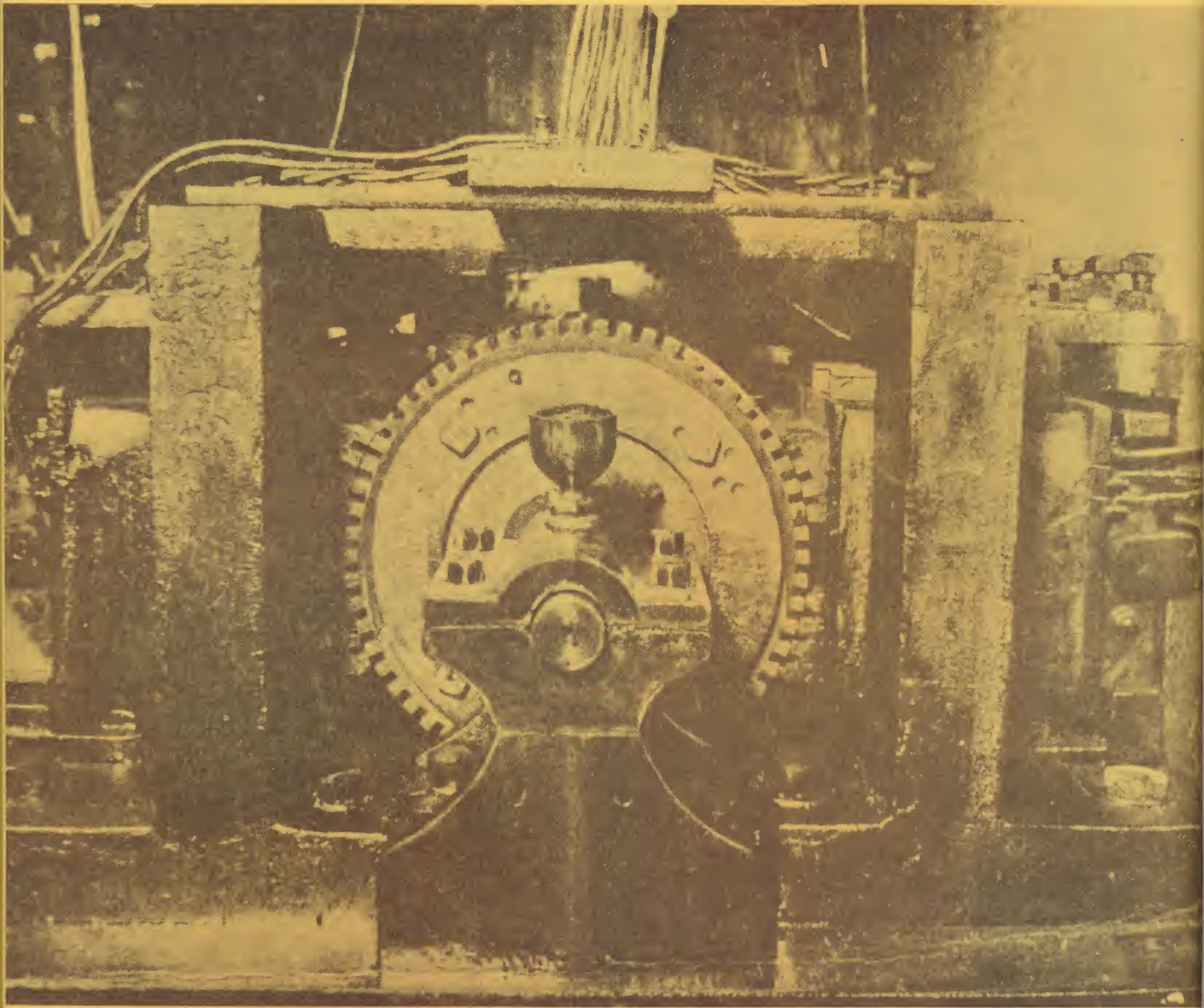


This was written in 1910 and subsequently modernized. If you have had trouble getting into calculus, this can probably do the trick. A bit of the author's prologue is printed below. $1.95 from: Macmillan and Co., 866 Third Avenue, New York, N.Y. 10022.

> Being myself a remarkably stupid fellow, I have had to unteach myself the difficulties, and now beg to present to my fellow fools the parts that are not hard. Master these thoroughly, and the rest will follow. What one fool can do, another can.



Volume 2 of a three-part series (volume 1 is *Motion, Sound, and Heat;* volume 3, *The Electron, Proton, and Neutron*) is perhaps not as immediately applicable as those books listed above, but it has the advantage of giving some historical perspective to the facts as well as discussing basic concepts like mass, action at a distance, etc. They are eminently readable. $0.95 from: The New American Library, Inc., P.O. Box 2310, Grand Central Station, New York, N.Y. 10017.



Compiled and written by
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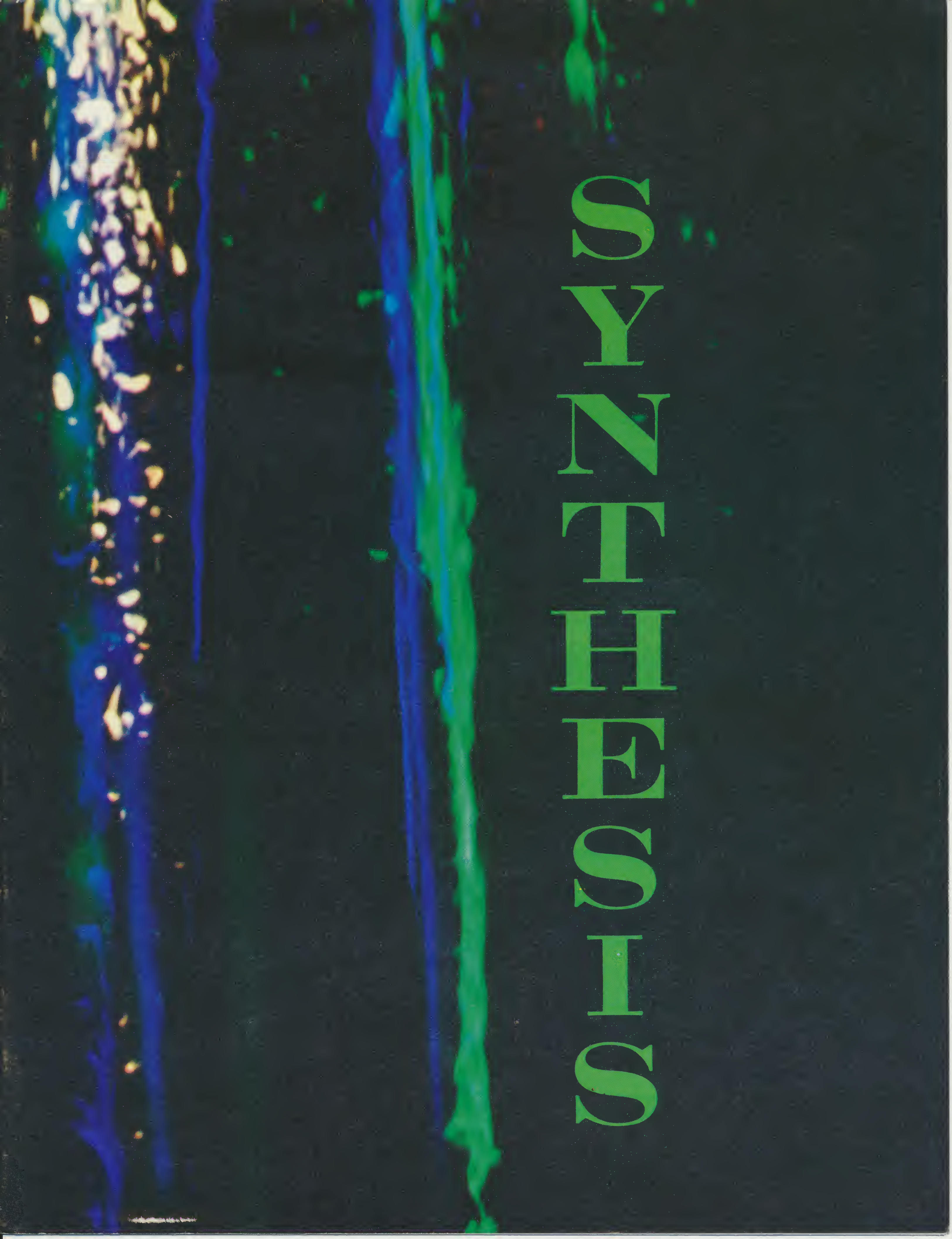

Letters

11-9-70

Synthesis:

As a member of your advisory board or whatever it is called, I should like to express hope that future numbers of *Synthesis* will be a bit better than your teaser issue.

A glossy format does not imply a useful or interesting journal. I am not saying that the format should be dull, but it would seem that your gloss was misdirected.

The article on the oscillator was trivial. As children of cybernation you should realize that in computer systems a 'pointer' is far more utilitarian than a literal representation of the data. You could have 'pointed' to an article on oscillators in any one of several dozen other publications in one or two lines thereby freeing up your pages (and budget) for things more uniquely suited to a magazine for *musician* readers.

Dave Friend's article is also a bit out of place. I realize that electro-musical scholars wishing to give their grad students something pithy to deal with will assign it for reading but who cares. Tonus will probably distribute it as an application note in the interest of business and here too *Synthesis* could have 'pointed' to it in a line or two.

Synthesis proposes to fill a need. What is that need? How are you filling it? Who is your readership?

Remember the business is electronic *music!* There are 11,000 publications dealing with electronics and several hundred dealing with music but none bridging the gap. What does a half-assed description of an oscillator (completely unsuitable for actual live or recorded use) have to do with a musician's attempt to produce or experience electronic music? Let's not set the business back. Let's advance it or at least keep up with it. What the world needs now is not another irrelevant artifact.

Gentlemen:

Thank you for the complimentary copy of *Synthesis.* The article by Dave Friend was interesting (although I had gotten most of the information about the ARP *VCO* from talking to him in Houston this summer.) Unfortunately, Friend's was the only technical article in a mass of dillettantish filler.

The review of Stockhausen's *Beethoven, Opus 1970* was quite superficial, speculative and full of wrong information. I can't speak for Stockhausen (I did study with him at Darmstadt in 1969) but it seems that neither of you gentlemen has ever seen the scores to *Kurzwellen* or *Prozession.* My ensemble has performed these pieces and we are doing a version of *Opus 1970* on a concert November 9.

You would know that the players not only play *controlled* responses to the tape excerpts, either with their instrument or with the tape itself (the volume of which they regulate), but they also respond to *instrumental* events as well – either to the event they just played or an event a coplage has played. The instructions given to the musicians are signs: +, -, and =, and certain combinations of these, which apply to dynamics, register, speed, number of segments/event, *et al.* There are *no verbal* instructions *per se* in the *score.* There are, however,

Peace.

A. J. Gnazzo

12-14-70

Gentlemen:

Your complimentary issue is really quite lovely – the production is splendid and the format offers something for all, at every technical or aesthetic level. I'm sure everyone will eagerly await the all too infrequent issues. (And hopefully they will arrive on time, as wasn't the case with the ill-fated precursor, *EMR.*)

One possible suggestion does come to my mind: Would it be possible to set up a technical advisory pool among interested readers? This pool could serve on a consultant basis, offering circuit design or system design solutions, or simple relaying the latest information on electronics industry developments which might find application in our art. This is especially needed in the domain of microcircuits where special function devices are being designed daily.

An additional suggestion deserves mention: How about soliciting articles (and subscribers too!) from the area of the visual artists? Kinetic sculpture, electronic theatre, environments, live electronic music – they're all so much siblings – would benefit from such a healthy interchange of ideas. And these artists are circuit designers, since they have no Robert Moog to do all the designing and packaging for them. At the present time there probably is no such format of a technical approach available to them; let us lead them to *Synthesis.*

Sincerely,

Raymond Weisling

three pages of discussion and explanation of the signs.

Please do not construe these criticisms as anything but constructive: you have my sincere wishes for the success of your most needed and promising journal.

Cordially,

Dr. Thomas Wells
Director, Electronic Music Studio
The University of Texas at Austin

Dictated by Dr. Wells, but typed and signed in his absence.

Dear Sirs:

I am enclosing a copy of a U.S. Patent, #3,539,697, issued to me on November 10th, 1970, together with a clipping from the *New York Times.* The The contents of the Patent may be of interest to you.

If you want to try a quick experiment take three one inch standard screws: 6/32; 4/40; 3/48; cut off the heads; put them parallel lengthwise on a multi-track tape; run a permanent magnet over each screw; put the tape on the playback and out will come a major triad. The mathematics is the proportion of 32:40:48, which reduced to the lowest common denominator equals 4:5:6. This proportion gives the fourth, fifth and sixth harmonics of the "Chord of Nature" resulting in a Major Triad in Just Temperament. At 15 ips, the frequencies will be 480: 600:720. You can get longer threaded rods at your hardware store.

I am also enclosing an article in the *Electronic Music Review* of January, 1968, dealing with some of my earlier experiments. This article was written by Gordon Mumma, who, I see, is on your Advisory Council.

Ads

The State University of New York at Albany offers an A.B. in Music with a concentration in Electronic Music. For Further information, write Electronic Music Studio, SUNY/Albany, Music Department, Albany, New York 12203. Two fully operational studios are available for student work.

Moog Synthesizer Model IIC-Ten months old and in perfect condition. Photograph on request.
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1	904-C Filter Coupler
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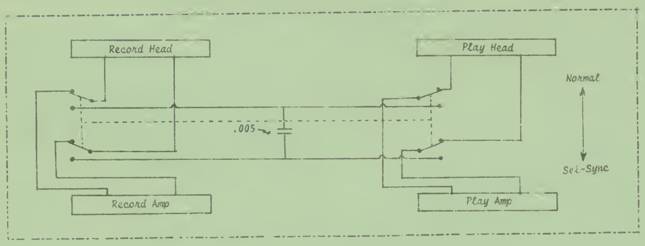
FOR MISC SECTION

ERRATA

Because two of the errors in this booklet seemed disastrous, we are forced to go to a do-it-yourself format. Please cut out the two inserts below and paste the first on page 5, the second on page 16.



The following column is a letter-syllable-word-phrase-sentence mix obtained by subjecting all the remarks by Henry David Thoreau about music, silence, and sounds he heard that are indexed in the Dover publication of *The Journal* edited by Bradford Torrey and Francis H. Allen (New York 1962) to a series of I Ching chance operations. The personal pronoun was varied according to such operations and the typography was likewise determined. The title is a scramble of *Thoreau* re *Electronic Music.*

MISC

SOME OPTIMISTIC PREDICTIONS (1970) ABOUT THE FUTURE OF MUSIC

Electronic music as such will gradually die and be absorbed into the on-going music of people singing and playing instruments.

Non-Western music in general and African and Balinese music in particular will serve as new structural models for Western musicians. Not as new models of sound. (That's the old exoticism trip.) Those of us who love the sounds will hopefully just go and learn how to play these musics.

Music schools will be resurrected through offering instruction in the practice and theory of all the world's music.

Most orchestras will wither and die leaving only a few dedicated regional music museums similar to the few Pro-Musica medieval ensembles we have now. Instead of orchestras young composer/musicians will form all sorts of new ensembles growing out of one or several of the world's musical traditions.

The pulse and the drone will re-emerge as basic sources of new music.

Serious dancers who now perform with no sound but that of their own movement, will be replaced by young musicians and dancers who will re-unite music and dance as a high art form.

Steve Reich (4/70)

Someone asked us to explain how to sel-sync a Sony. Meanwhile, someone else told us that the Sound Shack was into high-quality, inexpensive recording. John Valvo submitted the following.

Last year pre-recorded tape, for open-reel machines with four discrete channels, was released to the high-fidelity market. This release was small and came primarily from one company with wide distribution facilities, Vanguard Records. The offering came just after the release of several four-channel quadraphonic tape recorders to the component market.

Unfortunately the recording industry considered that particular segment of the market too small to continue pursuing it with any vigor, though interest still remained high. Continuous research is being done on other modes, such as disc, eight-track cartridge and cassette configurations.

Component retailers across the country found themselves with four-channel tape recorders and playback devices in their inventories without a ready market. The Sound Shack, located in Van Nuys, California, not much different from other retailers, found itself in basically the same position. There is one difference, however. It is located in the San Fernando Valley, a stone's throw from the hub of the music and recording industry. Dealing on a continual basis with various artists and technicians in the industry, the Sound Shack is very much aware of their particular needs.

The advent of the quad recorders opened up new areas of use (after minor electronic modifications had been performed on them) and was met by an eager market of musicians, arrangers and composers. These machines represented a major breakthrough for home-experimentation recording, without requiring an investment of three to four thousand dollars for the usual professional equipment.

The Sound Shack modified one of the first quad channel tape decks on the consumer market, the TEAC TCA 42, and used it successfully in the studio. The TEAC is a basic unit with seven-inch reel capacity, 7 1/2 and 3 3/4 ips speeds, three-motor transport with touch-button relay and solenoid operation. Its response characteristics are 50-15,000 Hz plus or minus 3 db at 7 1/2 ips, with a signal-to-noise ratio of better than 50 db, quite sufficient for most experimental and demo work.

The price of this unit is $695.00 (on the west coast). It requires a simple modification: a sel-sync type of switching system that will allow one to hear any or all previously recorded channel(s) played back in synchronization with the new one.

To accomplish this modification, the parts needed are one small chassis box (small enough to mount on the head cover of the unit) to house four miniature four-pole double-throw switches, four .005 miniature capacitors and approximately ten feet of one-conductor shielded microphone cable of very small gauge. These components would cost fifteen dollars or less.

The schematic circuit shows the modification necessary to sel-sync one channel of the TEAC; it is duplicated for each of the four channels.

The principle is simple. During normal operation, all is left as originally designed. When sel-sync operation is desired, the record head functions as the playback head for the channel in question. One is then able to monitor a previously recorded track while recording another track in sync.

Due to the internal differences between the playback head and the record head, there is a 12 db loss of volume and a slight loss of quality on the sel-sync channel when it is monitored. However, this loss occurs only during monitoring. The final tape, when played back through normal means (the correct playback head), will represent the tracks at full volume and in high quality. The small capacitor is placed across the record head only while it serves as a playback head. Its purpose is to eliminate any R.F. pickup incurred.

This basic circuit should work with any of the new quadraphonic four-channel recorders on the market, as long as they have the facility of individual-channel record modes.

A machine yet to be released, but at last word from the manufacturer due in April or May, is the Sony Model 854-4. This unit has professional features, such as 10 1/2" reel capacity and 15 ips speed, with excellent signal-to-noise and frequency-response characteristics.

The Sony unit will also have a variable-speed tuning control and will be available from the factory with the sel-sync feature already included at a cost of approximately $1,500.00. This is still a bargain, compared with the three- or four-thousand dollar prices of professional machines. Though this machine uses 1/4" tape, when used in conjunction with good quality mixing and monitoring devices, it should give one great latitude in experimentation and good sound quality for demo work.

Some of the mixing and monitoring devices the Sound Shack's studio uses are Shure's Model M67 transistorized mike mixers and Shure's Audio Master, a general equalizing device. The Sony Model MX12 mixer can be used in the final mix-down process or in monitoring during the sel-sync function. Among other items for the home studio could be included the Advent graphic equalizer, which gives one great control of the tonal quality of the signal at the reasonable cost of approximately $250.00.

All of these units are moderate in cost and one might find the total cost of such a studio to be less than the purchase price of one professional four-channel deck.

The Basic "Patch" for Sidewinder

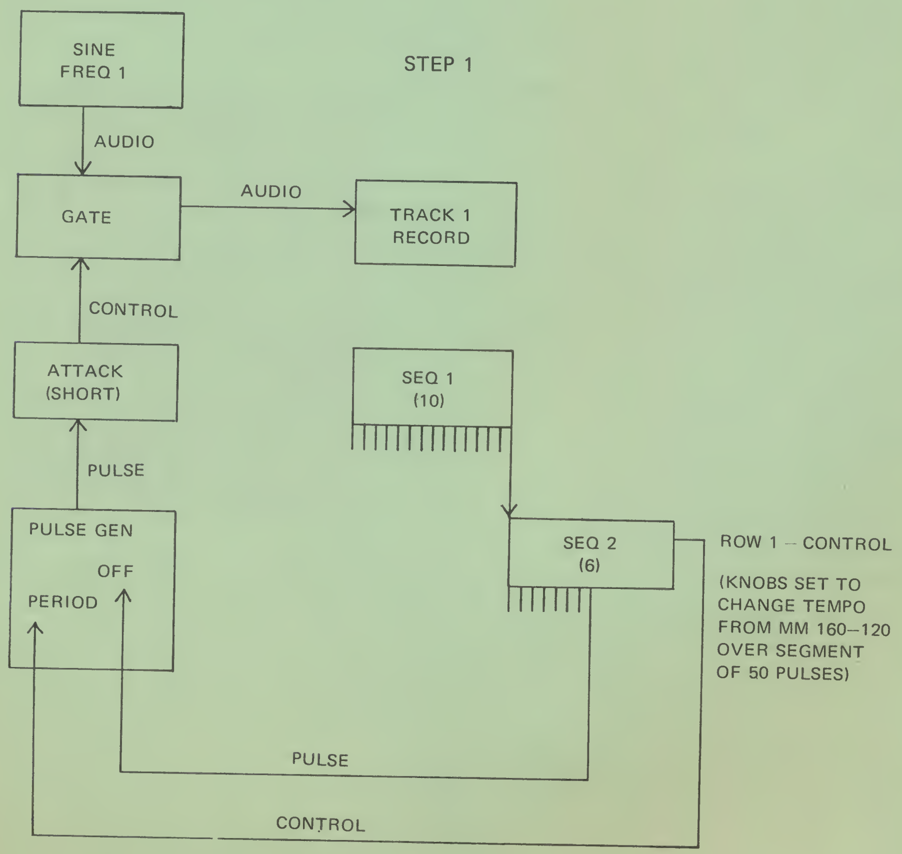
by

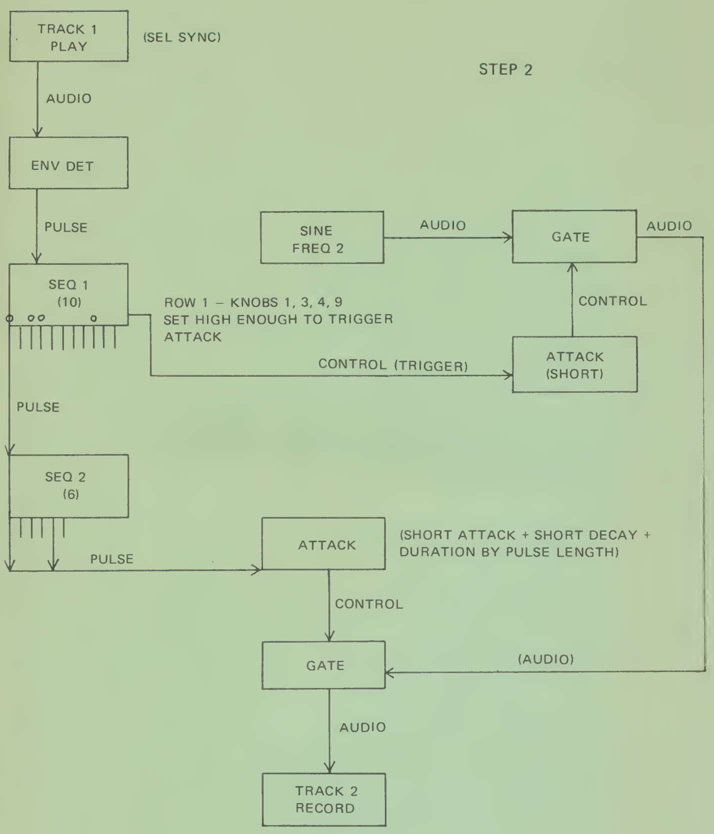
MORTON SUBOTNICK

The following example patch is designed to give the composer greater precision and the opportunity to add, modify, and rearrange his material without affecting the whole fabric. It was developed specifically for my composition "Sidewinder" which will be released soon on Columbia records. The problem which I needed to solve was how to be able to return to the composition at a later time and re-structure it from a stereo composition... to a quad composition and finally to a multi-media composition using light controls, live performers, and twelve speakers.

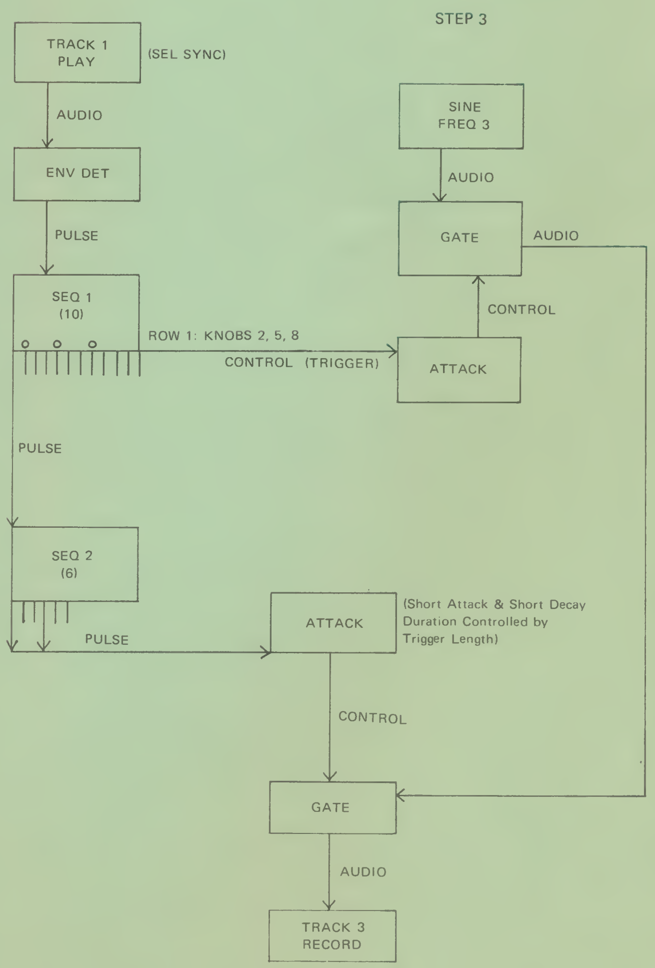
Because the control signals are always potentially present:

1. Any event can be placed in any speaker or any number of speakers.
2. Lights can be controlled in a precise relationship to any sound.
3. Indicator lights can be activated to give precise information to instrumentalist and/or a conductor.
4. Additions, changes, etc. can be made at any time on any aspect of the total fabric.
5. Further additions of control signals can be made at any time.
6. Additional "pulse clocks" can be produced (freq.1) to provide more flexible independence but with the degree of precision required by the composer.





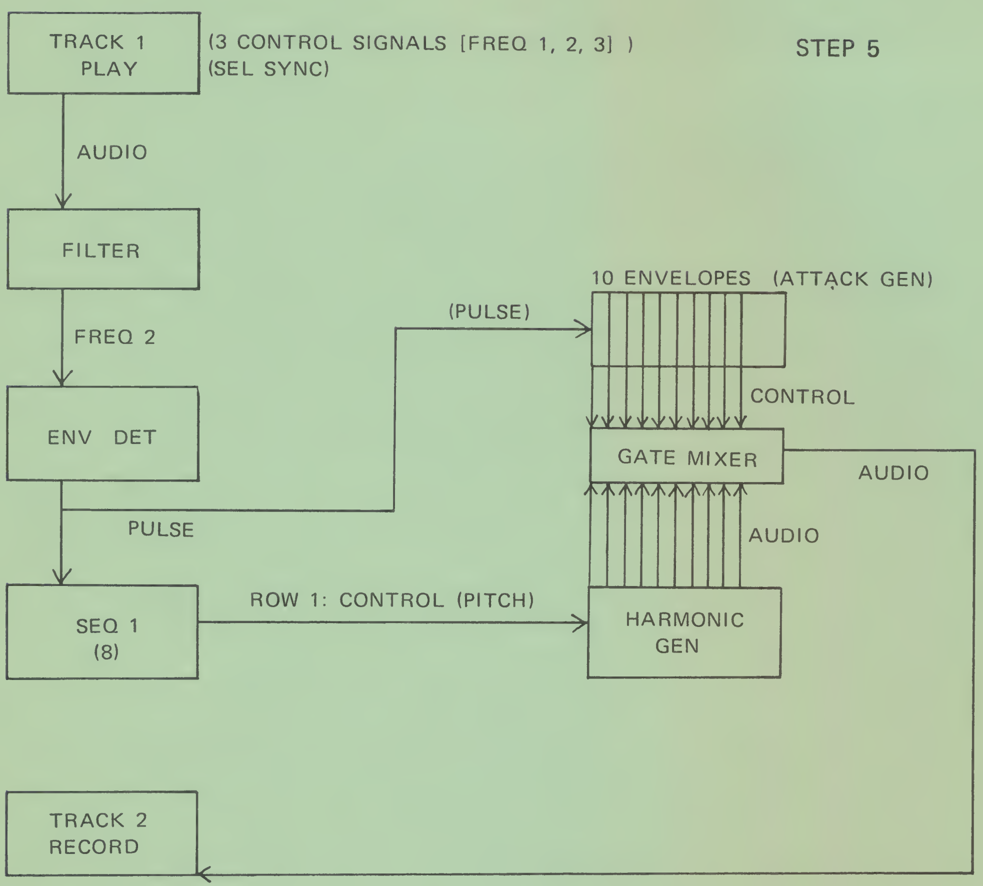
STEP 2
TRACK 1 PLAY
(SEL SYNC)
AUDIO
ENV DET
PULSE
SINE FREQ 2
AUDIO
GATE
AUDIO
SEQ 1 (10)
ROW 1 – KNOBS 1, 3, 4, 9 SET HIGH ENOUGH TO TRIGGER ATTACK
CONTROL
CONTROL (TRIGGER)
ATTACK (SHORT)
PULSE
SEQ 2 (6)
ATTACK
(SHORT ATTACK + SHORT DECAY + DURATION BY PULSE LENGTH)
PULSE
CONTROL
GATE
(AUDIO)
AUDIO
TRACK 2 RECORD



STEP 3
TRACK 1 PLAY
(SEL SYNC)
AUDIO
ENV DET
PULSE
SINE FREQ 3
AUDIO
GATE
AUDIO
SEQ 1 (10)
CONTROL
ROW 1: KNOBS 2, 5, 8
CONTROL (TRIGGER)
ATTACK
PULSE
SEQ 2 (6)
ATTACK
(Short Attack & Short Decay Duration Controlled by Trigger Length)
PULSE
CONTROL
GATE
AUDIO
TRACK 3 RECORD

STEP 4: MIX CONTROL TRACKS (1, 2, 3) TO NEW TRACK 1.

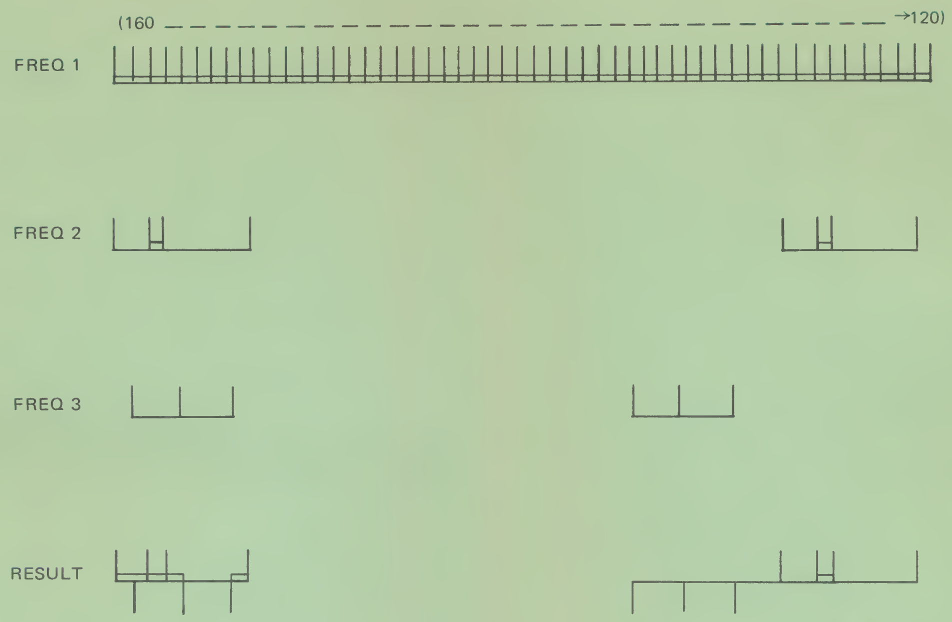
STEP 5



STEP 6: (record on track 3)
same as step 5 but:

1. Pitch 3 output of filter
2. Different setting on harmonic generator for unique "second voice" sound
3. Only six positions of sequence are needed

FRAGMENT PRODUCED BY STEPS 5 & 6

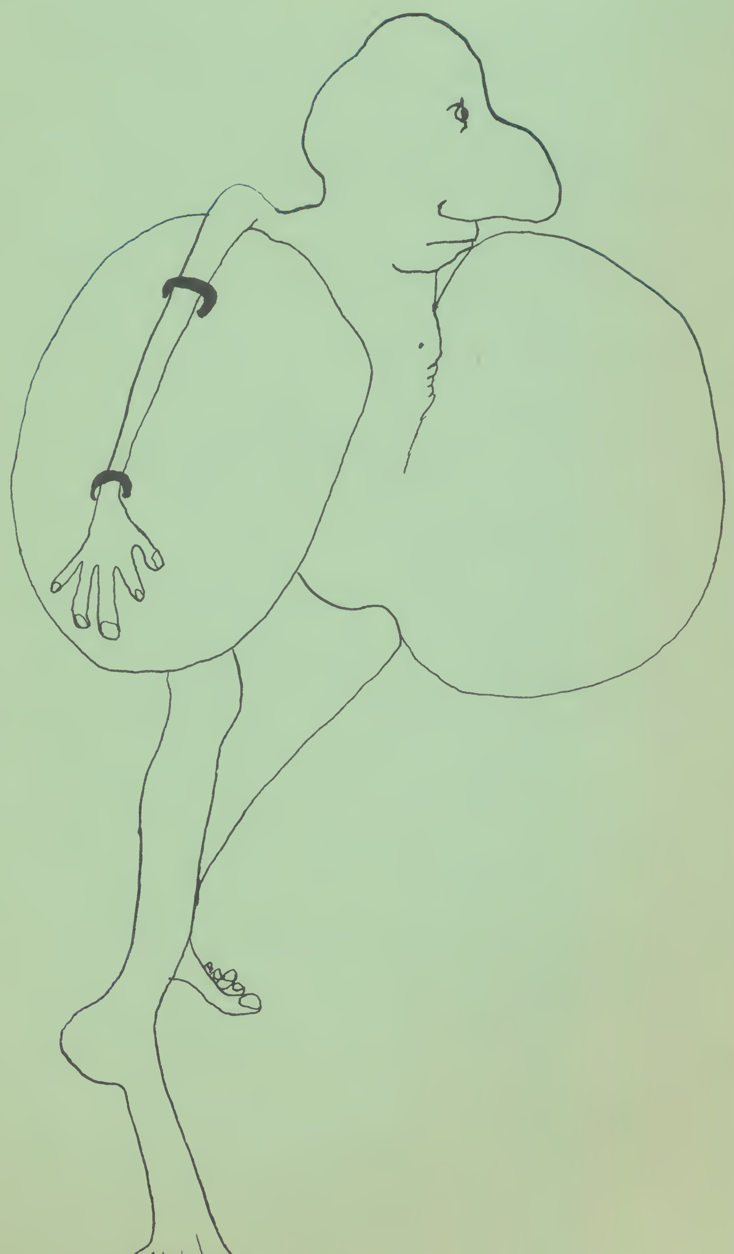


Variations of this technique are probably obvious... but here are a few examples:

1. Complex envelopes (either for amplitude control and/or filter control) require several attack generators.. the complex envelope can be recorded in the form of a control signal and later converted by means of an envelope det. The result would be... the original used a pulse source, at least four attack generators and a gate... the converted version used only one envelope det. and a gate, thus freeing previously used modules to be used again for other types of controls.
2. The patch diagram given here could easily contain the information to have a different amplitude and/or envelope on each event.
3. An entire composition can be laid out in time, envelope, overall amplitudes and spatial position. The details could be filled in later with far more modules on hand to control each individual event.

Note: The equipment represented here is the Buchla synthesizer. The envelope detector is a new "200" model module which has a pulse out as well as a control voltage out. (I have used pulse and trigger to mean the same thing throughout these examples).

Morton Subotnick presently has three albums available:
"Silver Apples of the Moon"
Nonesuch H-71174
"The Wild Bull"
Nonesuch H-71208
"Touch"
Columbia Masterworks
MS 7316



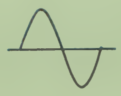
A BASIC DESCRIPTION OF OSCILLATOR WAVEFORMS

Electronic music synthesizers use oscillators to produce consistently repeating patterns of electrical intensity. A complete pattern is called a cycle. (The expression "cycles per second" has now been officially replaced by the term Hertz (Hz).) These patterns are used in two basic ways:

(1) Sound Source. A repeating pattern at 440 Hz can be converted into sound to produce the pitch we call A. The peculiarities of the particular pattern within the cycle will influence the tone-color we perceive.

(2) Control Function. Through voltage control, the change characteristics of oscillations can be used to vary virtually any parameter of sound - pitch, timbre, attack, decay, duration, etc. This changing of a parameter in sympathy with the pattern of a controlling function is called modulation. A simple example would be the application of a subaudible sine wave oscillation to modulate the frequency of another oscillator to produce a vibrato.

Oscillators produce basic waveforms, each with a characteristic harmonic content. The waveforms usually available on a synthesizer are the sine wave, triangular wave, sawtooth wave, square wave, and pulse wave. As the names indicate, the patterns produced are simple geometrical designs. These particular patterns were not selected necessarily because they resemble the timbres of acoustical instruments, but because 1) they are relatively easy to produce, and 2) they offer considerable variety in harmonic structure so that when combined, filtered, etc., the possibilities are myriad.

Sine Wave 

A sine wave is referred to as a simple wave, causing a "pure" tone, because it does not contain any harmonics above the fundamental.[1] In a sense, the sine wave is the essence from which all other waveforms derive. When we speak of harmonic content in any waveform, it should be appreciated that those harmonics are sine waves. The resultant waveform is a progressive summing of the instantaneous intensity of all the multiple-frequency sine waves. Thus, sine waves are as basic to waveform generation as basic colors are to subtle shades of color makeup.

As well as being called a pure tone, the sine wave can justly be called a natural waveform, because its time-dependent rise and fall of intensity is a natural expending and storing of energy in a dynamic system. When a natural device such as a taut string is prodded from rest by some form of energy, it responds to and stores that energy with eagerness to give it back to the donor. When released, the string will eventually return to its at-rest position. But first it will overshoot its mark, and the stronger the prodding action had been, the stronger will be the reaction. This reaction to change produces sine-function behavior. Even an object that does not tend to vibrate at a resonant frequency can be thought of as responding in many little sections with sine-wise vibrations at many different frequencies.

Figure 1 is a sine waveform. The x-axis represents the passing of time. The y-axis is used to show the intensity of the action at each moment in time. The zero point of the y-axis is the original rest position of the developed reciprocating action. Being the positive and negative peaks are the same, the amplitude of a waveform is expressed as an absolute value, from the zero point to the peak.[2]

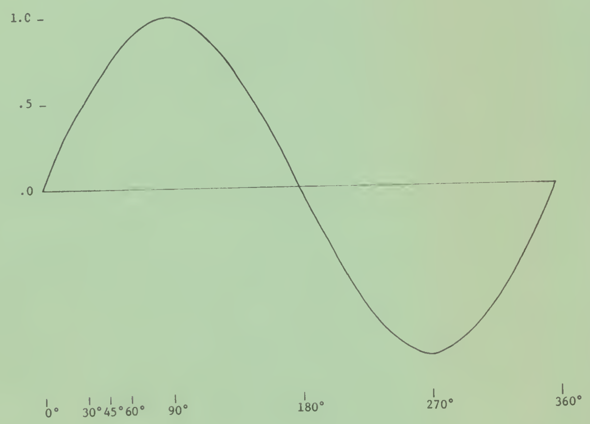
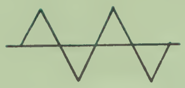


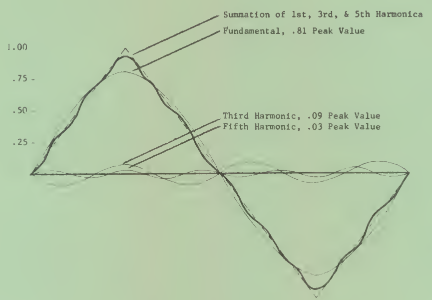
Figure 1. Sine Wave

[1]The term "sine" comes from the fact that the intensity at a given angle is the trigonometric sine function of that angle times the peak magnitude.

[2]Amplitudes can be expressed in relation to reference points other than the zero point to the peak. This is done by simply identifying the reference points in the expression. For instance, 10v P-P means ten volts peak-to-peak.

Triangular Wave 

A triangular wave is a constantly increasing intensity, then suddenly a decreasing intensity at the same rate of change. A mathematical operation called Fourier analysis[3] provides a means of breaking down this and other waveforms into their component harmonics with the relative amplitude of each. Figure 2 shows how the first three odd harmonics produce an almost triangular wave. (A triangular wave has no even harmonics.) The rapid decrease of harmonic amplitude with respect to the fundamental is understandable in that, of the waveshapes being considered, the triangular wave is geometrically closest to the sine wave.



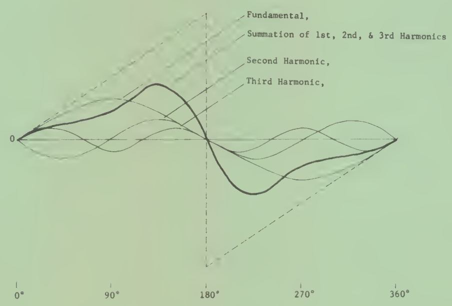
Harmonic Distribution
in % of Fundamental

3rd harmonic - 11%
5th harmonic - 4%
7th harmonic - 2%
9th harmonic - 1%

Figure 2. Triangular Wave

Sawtooth Wave 

The sawtooth wave starts out from zero base as a ramping action like that of a triangular wave, but it is suddenly made to go from maximum to minimum value in the least possible time. All harmonics are present in this waveform. Figure 3 shows the embryonic form of the sawtooth being the summation of the first three harmonics. This wave is rich in harmonics. The second harmonic is half the intensity of the fundamental. Even as high as the tenth harmonic, the magnitude is seven percent of the fundamental.



Harmonic Distribution
in % of Fundamental

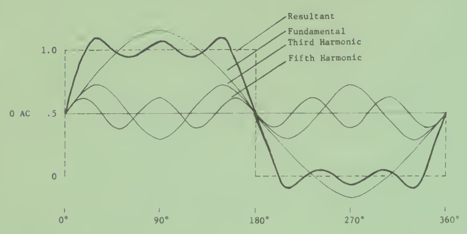
2nd harmonic - 50%
3rd harmonic - 33%
4th harmonic - 25%
5th harmonic - 20%
6th harmonic - 17%
7th harmonic - 14%
8th harmonic - 13%
9th harmonic - 11%

Figure 3. Sawtooth Wave

[3]The French mathematician Jean Baptiste Joseph Fourier (1768-1830) developed the mathematical system by which any single-valued and reasonably well-behaved wave shape can be analyzed as the harmonic summation of sine waves of different amplitudes and wave lengths. A remarkable achievement.

Square Wave

The square wave is simply a constant current or voltage turned on and off very rapidly at equal intervals. Figure 4 shows the first, third, and fifth harmonics and their resultant. (A square wave has no odd harmonics.)



Harmonic Distribution
in % of Fundamental

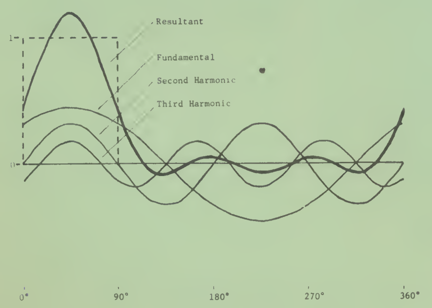
3rd harmonic - 33%
5th harmonic - 20%
7th harmonic - 14%
9th harmonic - 11%

Figure 4. Square Wave

Pulse Wave

The pulse wave is also called a rectangular wave. The pulse wave is formed in a similar manner to the square wave by turning on a constant current or voltage for an arbitrary time, then off for the remaining period of the repetition interval. The percentage of the cycle in which the energy is applied is sometimes called the duty cycle. That is, a square wave has a duty cycle of one-half. Figure 5 shows the first three harmonics and their resultant for a quarter-width rectangular wave.

Figure 6 shows what happens to the harmonic amplitude distribution as the pulse width is widened from a duty cycle of one-tenth to one-half. Harmonic amplitude approaches that of the fundamental as pulse width is narrowed. The progression goes retrograde as the duty cycle passes one-half. That is, a duty cycle of 3/4 has the same harmonic content as a duty cycle of 1/4; 2/3, the same as 1/3; 7/8, the same as 1/8, etc. Note that for any simple-ratioed duty cycle - 1/2, 1/3, 1/4, etc. - multiple harmonics of the denominators vanish.



Harmonic Distribution
in % of Fundamental

2nd harmonic - 71%
3rd harmonic - 33%
4th harmonic - 0%
5th harmonic - 20%
6th harmonic - 24%
7th harmonic - 13%
8th harmonic - 0%
9th harmonic - 11%

Figure 5. Quarter-width Pulse Wave

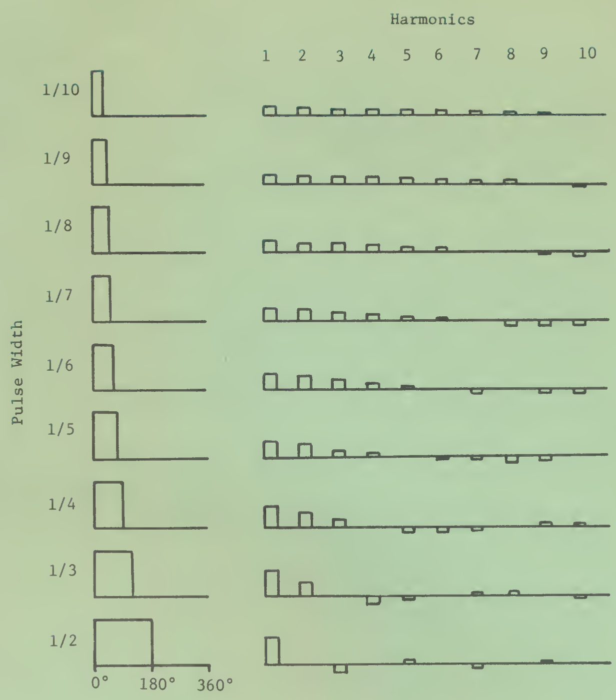


Figure 6. Relative Amplitudes of the First Ten Harmonics for Various Pulse-widths[4]

All of the foregoing discussion represents a part of what is called classical, steady-state acoustics. The steady-state condition is virtually non-existent in pre-electronic music. The ability of synthesizers to create a wide variety of steady-state conditions makes them well-suited for classroom demonstrations of harmonics, difference tones, and the like. This ability also renders them capable of producing the "pure" or "absolute" sounds which are so delightful to some musicians and are such an anathema to others. If one is in the latter camp, one learns early that one must always have some oscillators constantly involved in controlling filters, amplifiers or other oscillators to keep things subtly changing.

For a very readable sketch of some of the investigations into the physics of sound beyond the steady-state condition, the reader could check Fritz Winckel's _Music, Sound and Sensation; A Modern Exposition_ (1967) available at $2.50 from Dover Publications, Inc., 180 Varick Street, New York, N.Y. 10014.

H. R.

[4]Some of the amplitudes shown in this bar graph are drawn below the zero reference line. This indicates a phase inversion which, as far as is known, does not affect our perception.

John Cage

MUEAU *IC SIC L*ECTRONE rETHOR

sparrowsitA grosbeak betrays itself **by that peculia**r sq**ueakariE**ffect of slightest tinklin
g *measures sound*ness ingpleasa**We hear! D***oes it n*ot rather hear us? *sWhen he hears th***E**
Telegraph, he thinks**tho**se bugs have issued forthThe owl tou**ches the**
stops, wakes reverber**ations** d gwalky <u>In verse the</u>**re is no** *in*

herent music eo fittskestakes a MAN TO MAKE A R
O om silent It ta kes to m ake a roomIt is a young appetite and
the appetitefor i sHe Oesyssee mor ning You hear
S cream of great h awka yd gh body shelie being SILENCEIT WOULD B e noblest to sing with the
wind To hear a neighbor S inging! u it wood The triosteum a day or twob mtry They says
to-we e, to- WEECALLING TO H is team liv es heard over high open fi
eldsday ins tead Of the drum thensav pa with young birdswith YOUNG BIRDSFR om
a truc k ndat every po stt ed d ER OGLECTS IN TH e mean time o pi at so
piercing ders a cheTheyo ato sing in earnestseven now ch u asis u gddd gheas
u s iot ei gh c n ch siYou would thi nk music was being born again off Toads are still heard at eve
ningcrickets'Echo is an indepen dent sound Rhyme and tell his s
tory and bre athe himselfbre athe A sh rilL LOUD ALARM
IS incessantly rep eated theher oic hovers frOm over the pond t he clea r metalli c scream the y
w ENT OFF WI th a shiller craik They go off with a ho ars er chuck chuck noair hear
sharp, scre a ming notes rending th e air This sug gests wha t perpetual fl ow of spirit w
oul d produce A thr umming beyond and throughimportant E
VERY One can call to mind instances mil L TRE
ES CRE a kringin g We c ould not hear the b irdsIs the thi rd no
te confined to this S eason? Little fr
ogs begin t o peep toward sund own noonhorn is h eard echoi ng f
rom Sho re to shoreo f perchwith a loud, rippling

rustle think larmedand makes life seem serene and grandinexpressibly serene and grand apparently afraidwith more vigor and promise bellslee uttering that sign-like note verwarm and moist not much of the toad ev SO

Cheaply enriched for the listening of that word "sound" and am the scene of lifering ter viMusican d mel in m elody e in the next townand fireopenest all her senses n k swhich they do not rememberee ee AC h recess of the wooda ea what various distinct sounds we heard there deep in the woodshnand echo along the shore ymore than a rodnd a sa st eady breathing, cricket-like soundhunseen and unheard May it be such summer as it suggests into the woodsThere is inwardness even in the mosquitoes' humTrees have been so many empty music-halls heard from the dept h of the woodnight Thetoward nightther hour has serenity who amhumming past so busily lungs sweet flowingfrom farther or nearerhurried rippling notes in the yardas we passed under itsatand sat down to hear the wind roar swift and steady a perform er he never seestwo of themis perhaps hearD COMMUNicated so distinctly through the oar to the air acrossthe river directly against his eardifferently sounda hadthinks companiondisguiseTheas so the readand daywarblersandifMarHarm onying readus beas asmeltHe ipickerel timesIt is life Within life, in concen tric spheres my pden they givenoevidence they have heard uct He attaches i mportance to the actual worldtheir So there is something in the music t uShe we re child eorthe wind is not quite agreeable It prevents your hearing Two are steadily singing, as if co ntending th It will come up sweet from the meadowsorh We can f

orego the advantages of citiesclose There is a lower, hoarser squirming, screwing croak roundprb rne It or it may be in
the shutter andBeginning slowly, the beat sounds faster and fast
erIt is to the ear as sharpest fifeethe un s It is as palpable as the note h heard a
sm art tche-d ay-day-dayWe heard close to our ears I had HEARD them furth
er at first nd A A kingfisher wITH HIS CRACK,-cr-r-r-rackThus the spaces of the air a
re filledfor music all Vienna c ANNOT SERVe them moree seems to
be singing across the streamBeside, sounds are more distinctly hearda i in An
y place at all for music is very good thrill Such vibrating music would tHRILL TH
Em to deaththoughting theety All these sounds dispose our min
dsto serenity ASTWFK TP HEAR one warbleMen dance to it, ringand vibrate
where there is an empty chamber underneathourdiesr It dies away as soon as uttered di
essof awakened naturemake seasonwhen the Euterpeans drive througbHe hear
s it in the softened air some grains which stir within you ad sing a little while ey They hear
the croaking frogs at 9:00 P.M. dow tremble, imagining the worsttheof his a
ppr oachmter while they sit by the Spring! th hispa and
seemed to proceed from the wood lar ot rIThat noble strain he uTters that came with him heby
the character of that single strain N in every horiZOn e Is it not the
R. palustris? Orpheus Hear a slIGHT snoring
Of frog S ON THE BARED meadowsmo re known by the distance wfirstun h We go about tO find Solitude and Silence but
cherThe evening WIND IS Heard conversing with yout scratching the floorlike brEAK THE NS OF
WITH the first note byt to flow and swell the general quire b egwhich
their young ears detectin iteno T QUITE INAUDIBLE

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meters, hygrom eters, and barometers ch s some well-known march thisof the note, whittichee
ing thethe sione 1atr egular intervals for a long timest ts should say whistle
, if One could whistle for the notess some notes, then perfect warblesom thech ormerma n sick
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maypul TheyWilhourwh o b H E THEYNOTHMONTh
sson gtphrtee the re th e e ph r he tck toprii fibth ed t i rth a days heardc uckoo theyboy
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orifying going today itto change its positionsometimes a loud crackon inthis early breathi
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ND! THEY Stood, hearing wind and wateT They rks p strike earwe Hip-you, he-he-he-he
It was Longbefore the jingle comes I hear a robin singing before s unset son
g jingle comes up, soon to spRINGOO W
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char tee chuLIT ER GAIN THE OF
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solved g as the sound of a far-off glorious
life ooas though they dwelt in the depths a seem to be hushed rt to a

slow music ethat chiefly distin**guish**es *this seaso*n ewhich th*e mu* **rmer has a**
gita t *ed l to a strange*, **mad priestessh** *in s* **uch**
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twitteri*ng a day* or two h *a day or two by it* **s course**

ORGANIC KNOWLEDGE AND THE SCIENCE-HUMANITIES SPLIT

by Roger S. Jones

Do science and mathematics inspire man? Can an equation be as beautiful as a piece of music? Or are beauty and inspiration reserved only for the subjects of the humanities? Even more fundamentally, are science and the arts truly separable?

I believe that the separation between science and the humanities is a profound hallucination which can destroy civilization today, just as the imagined demons of yesterday destroyed men's minds. This rift has its source in man's personal inner being, rather than in his external social life. There is a basic unity of science and the humanities, and the realization of this unity can prevent great human disaster and can also nourish man's spiritual growth.

The distinction between objective science and human subjectivity has never been very natural to me. As a child, I became deeply interested in astronomy and spent many hours reading about the heavens. The celestial pageant of stars and planets, gradually developing in my mind, inspired me to learn much of a "technical" nature, but astronomy was never a pure science to me. My interest seemed always to proceed by combining the subjective with the objective view. Indeed without that magical human picture of the skies, all of the data on time-periods, distances, and sizes of the heavenly bodies would have seemed to me to be so much meaningless numerology.

In my senior year as a college physics major I became troubled by the separation of science from art. As the editor of a student physics magazine, I argued in an editorial that the greatest theories of mathematics and physics were, in fact, works of art. My case was based on the analogous creative processes of the artist and scientist. Whether right or wrong, what remains with me now is the determined attempt I made to convince myself that science is not an activity divorced from the humanities.

The division of science and the humanities is a more profound problem for me today than ever before, and is greatly influencing my outlook and my work. What matters most to me in science and mathematics are those ideas and theories which help shed light on the human questions we all seek to answer, questions of existence and meaning, and of life and death. One may argue that such quests lie in the realm of religion or metaphysics, or at the least, in philosophy. This is true, but it is also revealing, for it pierces to the very heart of our problem – the separation, in the minds of men, of the sciences and the humanities.

For centuries now in the western world we have believed that the human or subjective questions may be separated from the universal or objective ones, and this belief in turn has been reflected in the division among the various disciplines of knowledge. Today a reaction against this belief is mounting, as man's course of separatism and objectification leads him rapidly towards his own destruction. This revolt, however, can also be very dangerous, for there are those within it, who, in their extreme reactions and impulsive desires to turn the tide, would have us renounce reason and objectivity altogether. This, in my opinion, would be a still surer course towards annihilation, for it is not reason that is at fault. Indeed, this new emotional tide does not represent a trend toward repairing the separation between the subjective and the objective, but rather toward deepening that separation, with a mere shift of emphasis from the scientific to the human side. The solution lies rather in a return to the organic and holistic approach to life and knowledge that characterized early civilizations. Of course, we cannot simply adopt ancient ways, and ignore the experience and enlightenment of the last three thousand years. But we have much to learn through the combined wisdom of ancient and modern civilization. We must seek new means to integrate learning and experience and must employ science and reason to illuminate human questions, as did the ancients.

In the orient things have been different. The major eastern philosophies and religions have long taught

that man is not a discrete entity, but rather an organic part of the whole cosmos, and that he must sooner or later come into a harmonious relationship with all the forces and rhythms of nature. The eastern disciplines differ in their "programs" for achieving enlightenment, and some even reject altogether the notion of striving for this goal, but they basically agree that man has a universal identity and that our western dichotomy of object and subject or of life and death is but an illusion. It is unlikely that western society as a whole can embrace the wisdom of the east any more easily than it can return to the organic world of the ancients, for our way of life has for so many centuries contradicted the basic oriental philosophies. But the east, like the civilizations of old, can help us to become aware of the forces fracturing our disciplines and tearing us apart.

And so in my own struggle with this problem I have come to realize that the answer will not come from any one source or by following any ready-made path. Rather, each of us must find his own way to close and heal this modern wound, intellectually at the level of knowledge and learning, and emotionally at the level of personal and spiritual development. The eastern and ancient worlds can serve as important guideposts in this search. I find that I must open my own mind to explore avenues of these remote civilizations that I should never have considered a year or two ago. A case in point is astrology. It's most amusing that after years of training and experience in science, I seem to have advanced from astronomy to astrology. But that's the Aquarian Age for you.

Astrology holds many clues to help us overcome the dilemma of the science-humanities split. First, in terms of content, astrology is a remarkable instance of the kind of integrated approach to learning typical of ancient cultures. There is no subject I know of that thoroughly blends so many different disciplines: astronomy, geometry, arithmetic, statistics, logic, mythology, psychology, philosophy, religion, music and art. These subjects easily span much of what we normally consider as the sciences and humanities. Moreover, astrology carries its synthesizing approach into the practical sphere, for it seeks to employ the sciences in the service of human problems and personal growth. Of course, medicine is another example of a science for healing human beings, but then medicine, like astrology, is rather ancient. Astrology, in fact, goes beyond the intentions of medicine, for not only does it attempt to minister to man's psychological and spiritual needs, but it also helps him understand his place in the universe.

Secondly, in terms of form, astrology is founded upon the basic organic unity of man and the universe. It assumes no rupture between man and his environment or between the mind and the external world, as modern science characteristically does. This, beyond any ability that it may have to predict events or to explain personality, is why astrology is so meaningful to me. Carl Jung, who was greatly interested in astrology and who employed it frequently in analyzing his patients, has spoken of this basic unifying precept as "synchronicity." This is the notion that all things in the cosmos are synchronized with all other things, or perhaps more fundamentally, that any occurrence is a reflection of the basic nature and form of the whole universe and thus of all things and events within it. This is not a causal relationship but rather one of organic unity or holism. If astrology works, it is not because of any "influence of the stars," but rather because of this basic principle of the unity of all form. Thus astrology may be seen as one of many ways to "read" one part of the cosmos in another. The pattern of a man's life can be read in the pattern of his natal sky, for fundamentally they are one and the same. All patterns, all forms, are the same. It is the human mind that makes us see them as different. And the synchronous relationship, suggested by astrology, between all forms is an invaluable clue to the fundamental unity of the whole cosmos.

This unity means that any separation of subject from object, of figure from ground, or of the inner from the outer life, is an illusion. It is this illusion which lies at the root of our modern schisms and paradoxes. In astrology the heavens are seen to reflect the earth and the earth, the heavens. "As above, so below." Thus synchronicity is the embodiment in astrology of the ancient holistic wisdom of the orient. A subject more fertile in messages and hints for modern man would be difficult to find, for it suggests the organic synthesis of all content and form.

But astrology alone cannot supply the answers. It suffers from too strong a bond with the past to provide us with a truly modern solution to our problem. We must seek to incorporate the wisdom of the ancients and of the east with the knowledge and reason of the west. Thus I have been drawn back to modern science, and to its potential use in helping to explore man's ultimate questions, whether metaphysical or not. Many scientist-philosopher-mystics of the twentieth century such as Jung, Velikovsky, Watts, Ouspensky, Gurd-

jieff, Eiseley, Polanyi, Brown and Barfield, have made remarkable inroads into formerly taboo areas of thought and research, and it is precisely here that the revolt is overdue and welcome. These men have brought once more to light the great relevance that alchemy, astrology, and other occult subjects have for man's personal quest for meaning. These ancient sciences were not divorced from human questions as our modern ones are. It is only now, after many hundreds of years of suppression in western civilization, that the investigation of metaphysical and even occult questions may possibly be undertaken with some inkling of respectability, by people well-equipped with the methods of modern science and western reason.

These barriers between science and the humanities, mind and body, space and matter, life and death, distort the conscious thought of us all, and the need to topple these mental walls of division is important not only to scholars, in the sciences and humanities, but to all mankind. The time may well have come when men will begin seriously to use a new science to answer the question "Why?" in searching for answers to more human questions. For many years science has restricted itself to the more objective question "How?" and left metaphysics for the mystics. Indeed, the proof was in the pudding, for modern science has achieved enormous success. But in the twentieth century in spite of still greater successes, the depth of difficulty in physics has led an Oppenheimer to postulate the need for a new mathematics if we are ever to solve the nuclear riddle, and the complexities in mathematics have led a Russell and a Whitehead to give up hope of ever placing mathematics on a firm logical basis. In fact, the traditional quest of the mathematician to place all of mathematics on a firm logical basis as Euclid did with geometry may well end in complete failure. The great genius of Gödel has shown that any mathematical system of sufficient sophistication and complexity to be useful and interesting can *not* be treated axiomatically.

In modern physics, the influence of the observer on his system of investigation has been found to be severe and inevitable. We cannot, for example, measure an electron's speed without affecting it, and thus the observer is an organic part of the system. Einstein, too, has shown us that the very concepts of space and time are not absolute notions with an independent existence, but rather are always united with the observer and his frame of reference.

It is remarkable, in my opinion, that two of the most profoundly perplexing problems for twentieth-century mathematicians and physicists are not only philosophically related to each other, but also shed light on the basic subject-object dichotomy we are discussing. In theoretical physics the problem of "self-effects" has never adequately been treated. How, for example, does the electric field of an electron affect the electron itself? Why doesn't an electron explode under the influence of its own force? Or how ultimately do we view the source of a field as separate from that field? Quantum mechanics, for all its great successes, is plagued as much with this problem as is classical electrodynamics. In mathematics, on the other hand, the paradoxes involved in dealing with classes of sets are still unresolved. Here is an example (which will take a little thought to follow): All books may be placed in one of two categories – A) those books which mention or refer to themselves, and B) those books which do *not* mention themselves. But what about a book which lists all books of type B? Is it of type A or B? Reflection shows that neither alternative is logically sound!

Both of these fundamental difficulties stem from the attempt to separate a thing from itself, and thus to create a rift in the organic totality of the cosmos. The concept of an electron as used in physics may be self-contradictory as long as electrons are conceived of and treated as distinct entities, separate from all others in the universe. And the notion of categorizing and naming different objects which underlies the paradoxes of set theory may contain a very fundamental fault. For if our thought processes and language only reflect

the illusion of separateness and disunity then they can never lead to truth. The fundamental analytical method of science is at stake here! Can cause and effect, inside and outside or subject and object ever really be treated as separate and discrete? Perhaps a new revolution in mathematics and physics can answer such questions, but what we may really need is a complete upheaval, unifying the sciences and the humanities and all knowledge.

Already in science a new and more organic approach has begun to emerge (as, for example, the ecological viewpoint in biology). In education the interdisciplinary approach to learning is becoming important and is proving effective. And politically, too, it is clear that nations and races must solve their problems within a far greater and more unified framework than history has thus far provided.

The scientific revolutions of the last hundred years — the theory of relativity, quantum mechanics, transfinite arithmetic and non-Euclidean geometry — are too mind-shattering to be divorced from metaphysical significance. What does it mean to live in a relativistic universe and what does time as a fourth dimension represent to man? Can the interpretation of all matter as vibration illuminate the eastern action of life as illusion? What do transfinite numbers tell us about infinity, eternity, and existence? It is fantastic to think that the organic approach to knowledge and to the understanding of man and nature may be one and the same.

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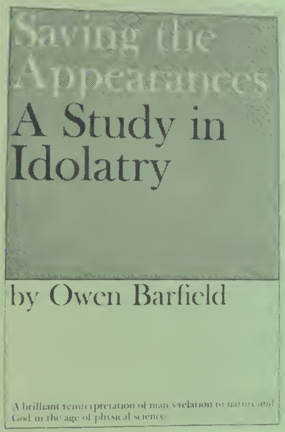
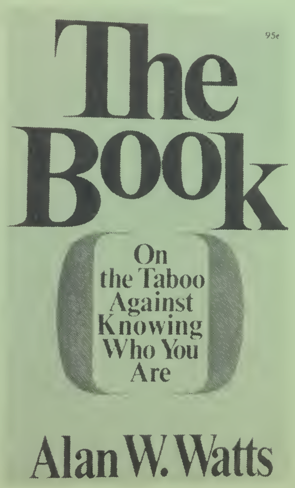


OWEN BARFIELD, *Saving the Appearances* (New York, Harcourt, Brace & World, Inc. n.d.) paper. This is a truly remarkable book in which the notion of the evolution of man's consciousness is explained through the study of the language and culture of earlier civilizations. Barfield argues that man's experience of the world has changed from earlier times, when it was one of organic participation with nature, to modern times, when it is one of separation from and objectification of the forces of the universe. He tries to show that all of our perceptions and experiences are representations, but that we treat them as reality and are thus guilty of a profound "idolatry." We are, however, on the path to evolving a new kind of 'participation with nature, one with definite religious and mystical overtones.

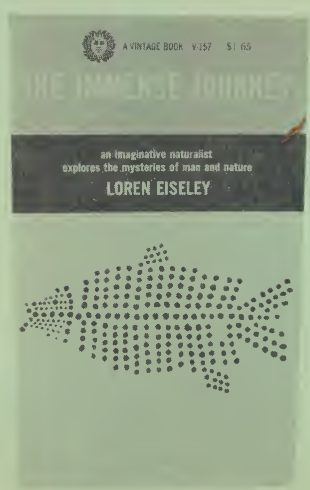


ALAN WATTS, *The Book* (New York, Collier, 1966) paper. Watts interprets for westerners the ancient Hindu philosophy of Vedanta. He explores the notion of the self and attempts to shatter the notion of an individual ego, separated from the rest of the cosmos.

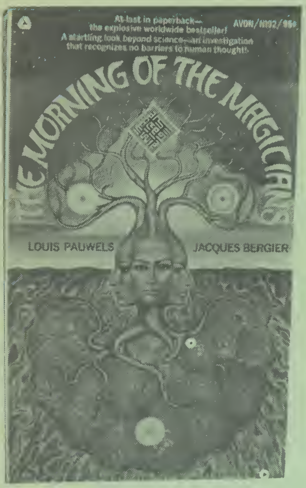
DANE RUDHYAR, *The Pulse of Life* St. Paul, Minn., Llewellyn Publns., 1963) paper. Rudhyar presents a beautiful introduction to astrology and an exploration of man's relation to the basic rhythms and patterns of nature and the cosmos. Astrology must be brought up to date to be made truly relevant and meaningful to modern man. His interpretation of the Zodiac and its relationship to the fundamental cycles of the solar system and the seasons is both profound and poetic. The stages of man's spiritual development are related to the astrological signs. (Picture not included.)

THEODORE ROSZAK, *The Making of a Counter Culture* (New York, Doubleday Anchor, 1969) paper. In a highly original and provocative exploration of the roots of the new cultural movements of youth in the modern world, Roszak raises the basic question of what kind of thought processes have produced the civilization we live in.

Contrasting the intellectual approach that has produced science but also technocracy with the more visionary mental experiences that we have subordinated, Roszak demands a return to a more "magical" world view in which creativity and community can thrive. This is the implicit message of the counter culture which we must heed.

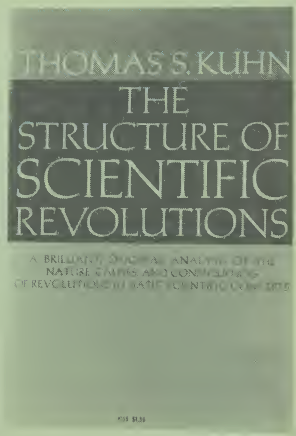


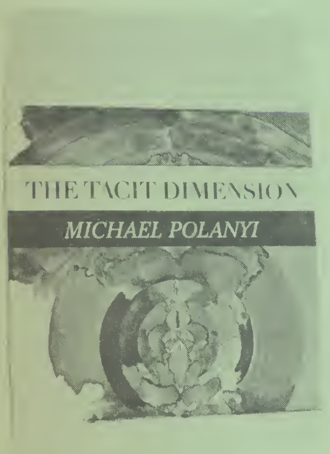
LOREN EISELEY, *The Immense Journey* (New York, Vintage, 1946) paper. This is a beautiful and poetic exploration of nature and man's relation to it. Eiseley reveals life's endless mysteries in his own experiences, departing into meditations on the past, wandering intimately with nature and returning to the present, all the while telling the story of man.



J. BERGIER and L. PAUWELS, *The Morning of the Magicians* (New York, Avon, 1963) paper. This is an eye-opening exploration of many areas that have been discredited and ostracized from the halls of science. The authors discuss astrology, alchemy, the myth of Atlantis, evidence of "magic" power in early civilizations, and methods of attaining higher states of consciousness and awareness. In an illuminating chapter called "The Magic Mind Rediscovered," digital and analogue thought and knowledge are contrasted. One is left with the inescapable feeling that vast realms of knowledge are available to us if only we can overcome the limits of linear rational learning and if we can rediscover our relation to the whole.

THOMAS S. KUHN, *The Structure of Scientific Revolutions* (Chicago, University of Chicago Press, 1962) paper. Making us review the nature and true character of science, Kuhn argues that science in normal periods presupposes an acceptable and conventional framework he calls a paradigm. Revolutionary crises occur now and then overthrowing this framework of science. Scientific work does not proceed until a new conceptual structure is accepted by the scientific community.





MICHAEL POLANYI, *The Tacit Dimension* (New York, Doubleday Anchor, 1966) paper. Through an analysis of the nature of scientific and objective knowledge and the relation between the sciences, Polanyi questions the very concept of objectivity. He argues that there is always an implicit or tacit component to knowledge making it impossible to objectively rationalize or deduce all that we know. Polanyi explores the moral and political implications of his theory, showing it to be incompatible with both positivism and Marxism.

MUSIC AS A GRADUAL PROCESS

I do not mean the process of composition, but rather pieces of music that are, literally, processes.

The distinctive thing about musical processes is that they determine all the note to note (sound to sound) details and the over all form simultaneously. (Think of a round or infinite canon.)

I am interested in perceptible processes. I want to be able to hear the process happening throughout the sounding music.

To facilitate closely detailed listening a musical process should happen extremely gradually.

Performing and listening to a gradual musical process resembles:

pulling back a swing, releasing it, and observing it gradually come to rest;

turning over an hour glass and watching the sand slowly run through to the bottom;

placing your feet in the sand by the ocean's edge and watching, feeling, and listening to the waves gradually bury them.

Though I may have the pleasure of discovering musical processes and composing the musical material to run through them, once the process is set up and loaded it runs by itself.

Material may suggest what sort of process it should be run through (content suggests form), and processes may suggest what sort of material should be run through them (form suggests content). If the shoe fits, wear it.

As to whether a musical process is realized through live human performance or through some electro-mechanical means is not finally very important. One of the most beautiful concerts I ever heard consisted of four composers playing their tapes in a dark hall. (A tape is interesting when it's an interesting tape.)

It's quite natural to think about musical processes if one is frequently working with electro-mechanical sound equipment. All music turns out to be ethnic music.

Musical processes can give one a direct contact with the impersonal and also a kind of complete control, and one doesn't always think of the impersonal and complete control as going together. By "a kind" of complete control I mean that by running this material through this process I completely control all that results, but also that I accept all that results without changes.

John Cage has used processes and has certainly accepted their results, but the processes he used were compositional ones that could not be heard when the piece was performed. The process of using the *I Ching* or imperfections in a sheet of paper to determine musical parameters can't be heard when listening to music composed that way. The compositional processes and the sounding music have no audible connection. Similarly in serial music, the series itself is seldom audible. (This is the basic difference between serial (basically european) music and serial (basically american) art, where the perceived series is usually the focal point of the work.)

What I'm interested in is a compositional process and a sounding music that are one and the same thing.

James Tenney said in conversation, "then the composer isn't privy to anything". I don't know any secrets of structure that you can't hear. We all listen to the process together since it's quite audible, and one of the reasons it's quite audible is because it's happening extremely gradually.

The use of hidden structural devices in music never appealed to me. Even when all the cards are on the table and everyone hears what is gradually happening in a musical process there are still enough mysteries to satisfy all. These mysteries are the impersonal, unintended, psycho-acoustic bi-products of the intended process. These might include sub-melodies heard within repeated melodic patterns, stereophonic effects due to listener location, slight irregularities in performance, harmonics, difference tones, etc.

Listening to an extremely gradual musical process opens my ears to *it*, but *it* always extends farther than I can hear, and that makes it interesting to listen to that musical process again. That area of every gradual (completely controlled) musical process where one hears the details of the sound moving out away from intentions, occuring for their own acoustic reasons, is *it*.

I begin to perceive these minute details when I can sustain close attention and a gradual process invites my sustained attention. By "gradual" I mean extremely gradual; a process happening so slowly and gradually that listening to it resembles watching a minute hand on a watch – you can perceive it moving after you stay with it a little while.

Several currently popular modal musics like Indian Classical and drug oriented rock and roll may make us aware of minute sound details because in being modal (constant key center, hypnotically droning and repetitious) they naturally focus on these details rather than on key modulation, counterpoint and other peculiarly western devices. Nevertheless, these modal musics remain more or less strict frameworks for improvisation. They are not processes.

The distinctive thing about musical processes is that they determine all the note to note details and the over all form simultaneously. One can't improvise in a musical process – the concepts are mutually exclusive.

While performing and listening to gradual musical processes one can participate in a particularly liberating and impersonal kind of ritual. Focusing in on the process makes possible that shift of attention away from *he* and *she* and *you* and *me* outwards towards *it*.

Steve Reich 10/68

The Function Generator in Music Synthesis

John A. Ball

[Abstract]

Function generators —arbitrary non-linear networks — are discussed in the context of electronic music synthesis. A function generator can often replace a voltage-controlled filter and the resulting circuit bears a close relationship to the equivalent block diagram of many conventional musical instruments.

To be submitted to Synthesis magazine

DRAFT: 27 March 1971

What's a Function Generator?

Function generators are common components in analog computer circuits. Any three-terminal network in which the output voltage is a single-valued function of the input voltage can be thought of as a function generator. Some common examples are circuits that have exponential or logarithmic characteristics, squaring and square-rooting amplifiers and trig-function generators. Also, an amplifier that saturates or clips is a common, and, as we shall see, a useful function generator. A function generator may not contain filters or any devices with hysteresis, because the output voltage would then be functional rather than a function of the input voltage, i.e., the output voltage would depend on the history of the input voltage as well as its instantaneous value.

Most currently-popular electronic music synthesizers (e.g., Moog, Tonus-ARP) do not use function generators as explicit circuit elements, although they do, of course, make use of such devices implicitly. In other words, there is usually no building block that is just a function generator accessible to the user. My thesis is that there should be.

Who needs it?

In the analysis of sounds produced by conventional musical instruments it is frequently instructive to draw an equivalent circuit, an example of which is shown in Figure 1. For comparison, Figure 2 shows a setup frequently employed in electronic music synthesis. To analyze trumpet tones, for example, the function generator in Figure 1 would be linear at low signal levels and increasingly non-linear as the input amplitude increases. Thus the harmonic content of the output increases as the amplitude increases—a well-known property of trumpet tones. In Figure 2 the same sort of sounds can be synthesized by sweeping a low-pass filter up in frequency as the amplitude increases. Is there any reason to prefer the setup in Figure 1 over that in Figure 2 or vice-versa?

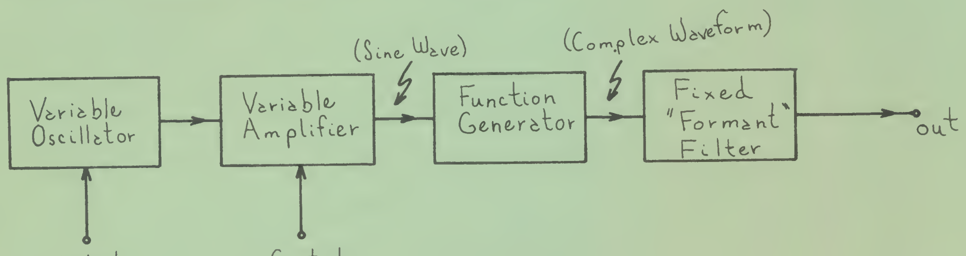


Fig. 1

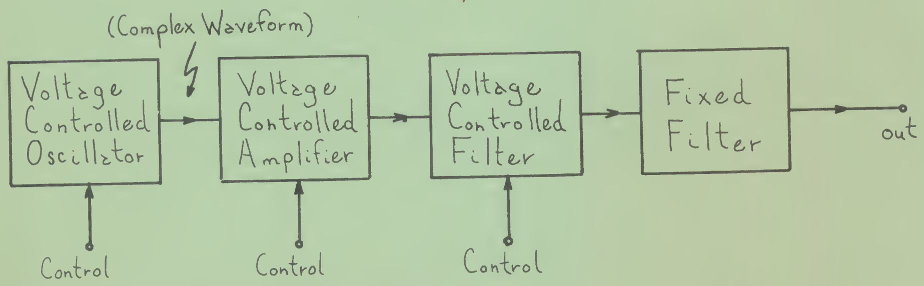


Fig. 2

Can it talk?

The criteria by which to judge synthesizers are difficult to define. It is clear, however, that versatility is likely to be a key word. We should not take too seriously the advertising literature which talks about "synthesizing any sound," but it is clearly desirable to be able to create a wide variety of sounds. Indeed, the frequently-played game of imitating conventional musical instruments is useful for demonstrating versatility. A synthesizer that can imitate such diverse instruments as a violin and a cymbal, very likely is also able to create a wide variety of new sounds.

The most complex naturally occurring sound is probably the human voice. Therefore, I suggest that we use the ability to imitate the human voice as one figure of merit for synthesizers.

Analysis of Arbitrary Function Generators

It is clear that a function generator with a sine wave input will produce harmonics in the output and that a function generator with a complex waveform input will modify the harmonic content in some way. This section shows how to analyze function generators in terms of the harmonics they produce with a sine wave input, and how to synthesize an arbitrary output spectrum.

An arbitrary function generator can be characterized by the output voltage f(e) that corresponds to an input voltage e. We wish to find the Fourier spectrum of f(e) for an input sine wave, for example, $e = \cos \omega t$, where $\omega = 2\pi v$ is the frequency. The solution to this problem involves Chebyshev T polynomials, because the recursion relation for these polynomials, namely

$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x),$$

has the same form as the recursion relation for cosines,

$$\cos[(n+1)x] = 2\cos[x]\cos[nx] - \cos[(n-1)x].$$

Let us expand $f(\cos \omega t)$ in a Fourier cosine series,

$$f(\cos \omega t) = \sum_m A_m \cos(m\omega t)$$

where the A_m are determined from

$$A_m = \frac{2}{\tau}\int_{-\tau/2}^{\tau/2} f(\cos \omega t)\cos(m\omega t)\,dt.$$

Now let us expand f(x) in a Chebyshev T polynomial series,

$$f(x) = \sum_n F_n T_n(x),$$

or

$$f(\cos \omega t) = \sum_n F_n T_n(\cos \omega t) = \sum_n F_n \cos(n\omega t),$$

because

$$T_n(\cos x) = \cos nx.$$

thus, we have

$$A_m = \frac{2}{\tau}\int_{-\tau/2}^{\tau/2} \sum_n F_n \cos(n\omega t)\cos(m\omega t)\,dt = F_m.$$

This result means that the spectrum of $f(\cos \omega t)$ contains harmonics with amplitudes proportional to the corresponding coefficients in the Chebyshev T polynomial series expansion of f(x). Or, since we are really interested in synthesis rather than analysis, we may say that an arbitrary spectrum for $f(\cos \omega t)$ may be synthesized by adding the proper amounts of each of the T polynomials into f(x).

This may actually be done in practice using a scheme for generating the T polynomials based on their recursion relation (equation (1)). An outline of such a scheme is shown in Figure 3. Note that each polynomial beyond the first requires an analog multiplier and an operational amplifier. The scheme would allow one to build a function generator having a knob for the amplitude of each T polynomial so each knob would control the amplitude of the corresponding harmonic in the output waveform. A device with similar capabilities is already available, the Hammond Organ.

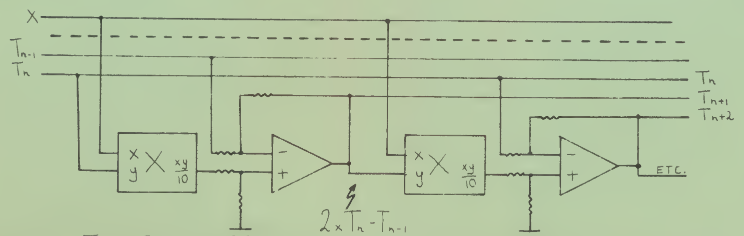


Fig. 3

Is it practical?

In practice, function generators can be quite simple in design although not necessarily simple to analyze. For this reason, experimenting with the sounds produced by function generators is particularly intriguing. The preceding analysis omitted explicit mention of the amplitude of the input voltage. However, for most function generators, the relative amplitudes of the harmonics in the output are a strong function of the amplitude of the input voltage. In music synthesis, the most useful function generator is probably one in which the relative strength of the higher harmonics increases with increasing amplitude, as mentioned previously in connection with Figure 1. (The opposite case produces rather unmusical sounds.) Fortunately, such a function generator can be simple and inexpensive; just a saturable amplifier will often do.

An Asymmetrical Clipper

Figure 4 shows a particularly simple but quite versatile function generator, an asymmetrical clipper. The small load resistor reduces the clipping level of the operational amplifier. This load resistor can be variable if desired. However, variable gain at the input as shown is usually satisfactory. The amplifier should be short-circuit proof, but is otherwise not critical.

At high gain this circuit produces variable-duty-cycle square waves which are useful, for example, in producing string-like timbres. The symmetry control varies the duty cycle and this in turn controls the zeros in the spectrum. At lower gain, brass- and woodwind-like tones can be produced if the voltage-controlled amplifier precedes the clipper as shown in Figure 1.

Figure 5 shows another simple but desirable function generator. The analysis of this one is left as an exercise for the reader.

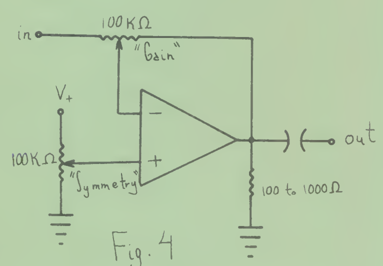


Fig. 4

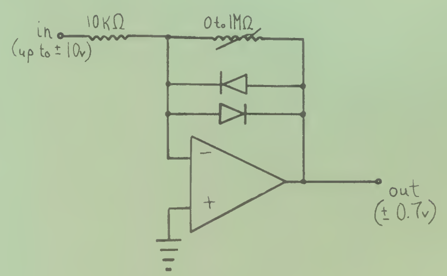


Fig. 5

So what's new?

We have described a synthesizer setup which is simple and inexpensive and capable of producing quite complex sounds without a voltage-controlled filter, but have we anything really new? Can a synthesizer with a function generator produce sounds which cannot be duplicated without a function generator? The answer is no, but with a qualification. If we have available an arbitrarily complex voltage-controlled filter, we can duplicate whatever can be done with a function generator. However, it sometimes requires a very complicated voltage-controlled filter to duplicate the effect of a rather simple function generator. Therefore, the practical versatility of a synthesizer will be expanded by the addition of function generators. I believe that other synthesists will find experimenting with function generators rewarding.

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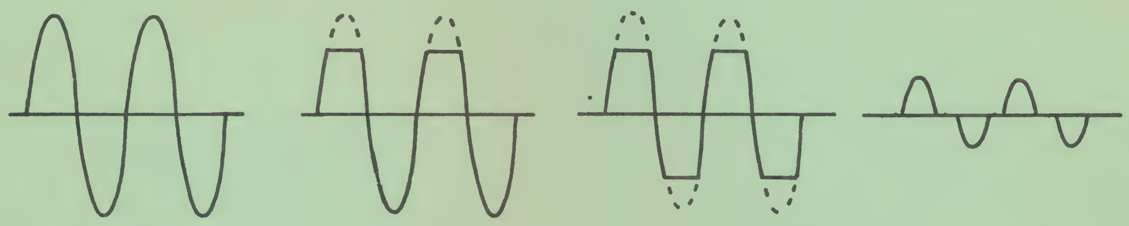
Handbood of Mathematical Functions, ed. by M. Abromowitz and I. A. Stegun, National Bureau of Standards, U.S. Government Printing Office 1964; Dover 1965. (See p. 778 et al. for Chebyshev polynomials.)

About the author: John A. Ball is a radio astronomer with Harvard University whose hobby is electronic music.

RESPONSE TO JOHN BALL's "THE FUNCTION GENERATOR IN MUSIC SYNTHESIS"

This paper is mathematically and scientifically sound. However, given that most readers of *Synthesis* are intelligent but not necessarily conversant with the mathematical notions involved in this paper, I feel that the article could be expanded to provide the reader with an increased understanding of the concepts involved. This is typical of scientific papers, however, *Synthesis* is not a scientific journal and the purpose of the writing should be to enhance the understanding of a particular subject. The general level of mathematical sophistication among our readers, I feel, warrants an expanded discussion of the subjects treated in this paper.

The concepts of "linearity" and "non-linearity" might be explained a little. It would probably be helpful to mention that a sine wave contains no harmonics and that any distortion added to a sine wave by an electrical circuit will introduce harmonics. The nature of this distortion will cause different harmonics to be generated and in different proportions. A function generator is designed to produce such distortion. (Figure 1 shows a sine wave and several possible distortions of a sine wave, symmetrically-clipped sine wave, an assymmetrically-clipped sine wave, and a sine wave with "crossover distortion," also easily produced. Clipping and crossover distortion, by the way, are the most common kinds of functions, which Hi-fi designers go to great pains to eliminate because of the harmonics they add to a 'clean' signal.)



pure sine   assymmetrical clip   symmetrical clip   crossover distortion

A function generator has an input and an output, as the paper states. Examples might show how harmonics are added by changing the amplitude of a sine wave input.

All function generators have fixed input/output characteristics which are usually easy to draw on an X-Y graph. This graph shows the input/output characteristics for a function generator which would produce assymmetrical clipping and hence *increased* harmonic content as the input amplitude is increased:

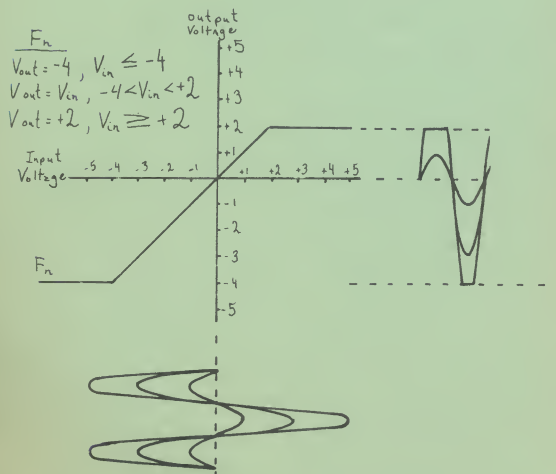


Fig. 2

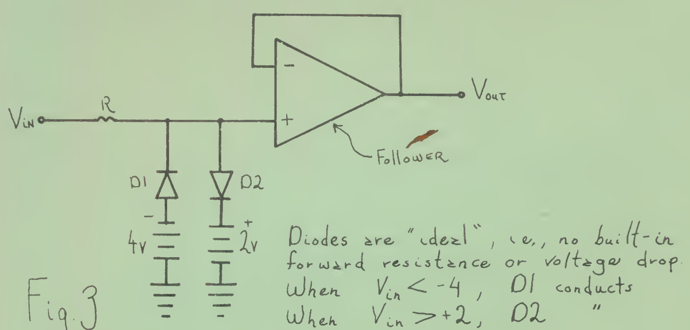


Fig. 3
Circuit to produce function in Fig. 2

Other kinds of function generators produce *less* harmonics (in proportion to the overall output) as the input amplitude is increased. Here the lower amplitude sine wave produces more harmonics than the higher amplitude sine wave.

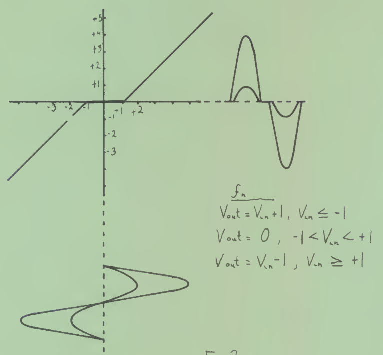


Fig 3

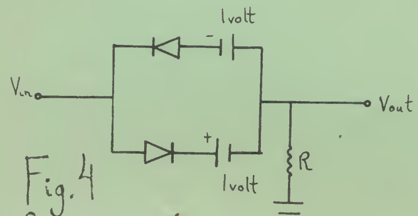


Fig. 4
Circuit to produce function in Fig. 3

In the concluding paragraph of the "Can it talk?" section on page 3, the author establishes voice synthesis as a criterion, but never brings this criterion to bear on his later discussions.

The introduction to the mathematical analysis is totally inadequate for the average reader. If one feels that a mathematical treatment of the subject is necessary as in this paper, I think that a parallel discussion should go along with the mathematical development which explains in layman's terms exactly what one is trying to prove mathematically. Terms like Chebyshev T polynomials, recursion relations, Fourier series, etc., will be Greek to 95% of our readers. This stuff is fine for the remaining 5% but should be otherwise supplemented for the laymen reading the article by an introduction to some of these concepts rather than losing him in a sudden flurry of equations and transforms (page 4). What is needed here is a more practical look at some examples of function generators and the effect of particular function generators on an input.

The only problem I see with the mathematical treatment *per se* concerns the premise that "we are really interested in synthesis rather than analysis." If this is so (it is really), why does the author state that an arbitrary spectrum for $f(\cos \omega t)$ may be "synthesized by adding the proper amounts of each of the T polynomials into f(x)" without first explaining a *practical* way to produce these harmonics? Certainly the implication at the end of page 5 that a function generator can more simply produce these results than a complex filter is questionable if the author's Figure 3 is supposed to be such a "simple" system.

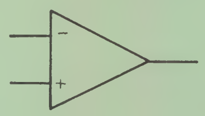
Ball's Figures 4 and 5 are closer to practical schemes, but I don't think the average reader will be able to figure out how they relate to the mathematical development or how they satisfy the conditions implied by the second paragraph on page 5 (about the Hammond organ idea). The fact is they don't. In the same sense that a simple ARP 1006 low-pass filter is limited to a certain range of timbres, so a simple function generator (as in Figures 4 and 5) is limited even more, assuming that a sine wave is the only input. However, the author's stipulation that *certain* formats can be generated more economically by function generators operating on sine waves rather than by filtering complex waves is certainly his most important point. And he is absolutely right. And there should be function generators on synthesizers. The guitar manufacturers learned this a long time ago. Remember the "fuzz box"? Incidentally, the ARP 2600 has a clipping amplifier built in for such purposes, our first accessible function generator. One other function generator accessible on the ARP and Moog synthesizers not considered in the author's statement ("there is usually no building block that is just a function generator accessible to the user") is the modulator which can be used as a simple squaring amplifier: $V_{out}=(V_{in})^2/k$. This function is obtained by feeding a signal into both inputs of a modulator. The result is not too impressive, however. It is amplitude-independent.

Finally, to get back to the business about synthesizing a voice, I should point out that the mouth is a low-pass filter with variable cut-off frequency and variable resonance, much like the ARP 1047 filter, with a 12db per octave rolloff. The vocal cords produce a complex waveform which is subsequently filtered by the vocal cavities of the throat and mouth, systems which can be described mathematically and translated into analagous electronic filter systems. A violin produces a simple sawtooth at the bridge (the resin on the bow sticking to the string, pulling it along, and then letting it slip back to its original position) which is filtered by the body of the violin. The process of creating this sound by conventional "subtractive" synthesis is obvious, although very cumbersome (the violin body is an incredibly complex filter). The author should bring us out of the dark on how these same kinds of results might be realized with function generators in practical electronic terms.

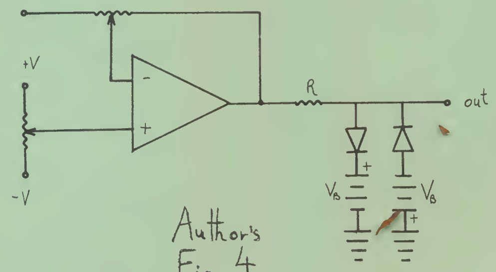
In the last paragraph the author states "it sometimes requires a very complicated voltage-controlled filter to duplicate the effect of a rather simple function generator." Very, very true. Just as true is the converse, however. It can require a very complex function generator to duplicate the effect of a rather simple filter. I think the trade-offs of specific devices should be further explored.

4/10/71 David Friend

P.S. I would suggest that you never treat the operational amplifier symbol as anything other than

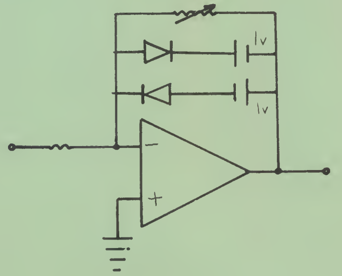


an ideal operational amplifier. The author's circuit in Figure 4 depends on physical limitations of certain amplifiers that are currently on the market. Give the amplifier a part number. I think the Fairchild μA741 would do the trick. However, the operation of this circuit will still be obscure to someone who has not worked with these devices. A "representative" circuit using "ideal" components would be more in keeping with the author's technical approach.



Author's Fig. 4

Similarly the author's circuit in Figure 5 would not work if we had more ideal diodes. Again, a representative model might be more instructive to those who don't have a feel for the semiconductor physics involved:



Author's Fig. 5

FOUR VIEWS
of the
MUSIC DEPARTMENT
at the
UNIVERSITY OF CALIFORNIA, SAN DIEGO

MUSIC DEPARTMENT UCSD

by Wilbur Ogden

Chairman of the Department

Art institutions in America with occasional exceptions continue to exhibit a lack of constructive influence on our society as well as a posture of timidity in relation to the new and experimental. Yet there is beginning to emerge a belated but determined intent among progressive artists and educators to counter this culturally anachronistic stance.

Fortunately, there is also a growing realization on the part of our political leadership that the creative artist *is* essential to the reseeding of a healthy society. If the arts are to function effectively within the American cultural environment, additional possibilities for a more direct influence on society must be developed.

In an unpolemical way, the thrust of the music program at the University of California in San Diego recognizes the creative artist's peculiar view of life as expressed through his continuing search for new realities. The UCSD instruction program is based on the tacit assumption that any significant educational thrust must center itself on creative searching if cultural relevance and social influence are to be realized.

Today's world of electronic technology continues to provide the contemporary musician with stimulating resources for his creativeness (and so it does in UCSD's graduate and undergraduate programs of instruction) often on as casual a basis as did the piano within a now conventional music curriculum.

Of even greater influence on the UCSD instructional program, perhaps, is the condition of today's creative language. Its present non-hierarchical state, mainly the breakdown of its semantic postulates, allows the mixing of noise and musical sound and the mixing of media. This has stimulated into being methods of music learning that encourage creative essays in sound among non-musicians and that insist on experimental studies related to their media among professional performers of music.

The present condition of music's creative language has unsophisticated the art to an extent that makes available to *everyman* musical uses of imagination and intuition, perception and judgment, and even a creative sensitivity to structural relationships. That availability, when fully realized, could modify *everyman's* present value priorities as well as his more anachronistic views of art in the world. It could impress upon *everyman* the social value of creativeness: if it would, we might dare hope for more constructive social and cultural environments.

When viewed *grosso modo,* this continuing confidence in artistic relevance is seen to inform the curriculum and practice of the University of California's music department in San Diego. Innovation is active, primarily at the graduate level of instruction where the M.A. and the Ph.D. degrees are offered, and also at the broadest level of instruction where the general student satisfies his college fine arts requirement.

Although the undergraduate music major at UCSD does participate in a progressive environment *per se,* his education tends to reflect the faculty's concern for developing in his traditional musical abilities and values. Beyond a considerable emphasis on the educational value of new music, beyond the casual integration of electronics as support for all music study, beyond specific instruction in music electronics and the availability of seminars in experimental theory and performance one must look to courses designed for the *general* student for evidence of radical innovation in the undergraduate curriculum.

II

Some four hundred University of California students, most of them freshmen, participate each year in the creative process as it relates to music. They improvise together, they construct tape pieces, they record the peculiarities of their environment, they devise notation systems, and they plan, rehearse, and present to their colleagues performances of sound structures of several minutes duration and of considerable complexity.

At various times, coinciding usually with campus performances, these students are called upon to attempt critical judgments of both the music and its performance, hopefully bringing into play the fruits of their own creative labors. They are also encouraged to develop the ability to hear more discriminately through a variety of controlled listening problems that isolate and bring to attention the elements and processes of music.

The tape recorder is near-omnipresent in these courses. It functions as an indispensable tool for critical review of one's own efforts, and it becomes an active music-making instrument in its own right. For example, the close-miking of marginally audible sounds allows the use of convenient but unorthodox sound sources such as paper or rubber bands. The overlaying of a recorded first improvisation with a second and third enlarges "the orchestra" and complicates the musical texture. Such projects can teach the student more about the musical process than one may expect from a music appreciation lecture or a textbook demonstration.

Like certain games employed with sensitivity training, musical improvisation enlivens personal and sensory interactions. When one participates in a musical group improvisation, one's imagination cannot run rampant at the expense of group interaction or of some aesthetic point of view collectively held. In this real-time process decisions are quickly made, musical propositions advanced and those of other individuals recognized and supported. A variety of social, aesthetic, psychological and physical responses continually interact, co-existing beyond the domain of verbal language.

Non-verbal improvisation exercises the rusty wellsprings of personal and social responses while disengaged from role playing or the acting-out of real-life simulations. Musical improvisation places us in direct contact with the reality of our own biological, psychic and social instincts and rhythms. We learn quickly to adapt these in constructive, creative ways so as to more fruitfully interact with others in pursuit of common goals.

Within this particular educational framework at San Diego, improvising must lie outside the range of technically disciplined performance. Non-music majors are, of course, rarely performers with disciplined instrumental and vocal techniques. Anyway, habit and cliche too often turn up as bedfellows. Habits inculcated by efficient but narrowly functioning performance techniques will tend to inhibit imagination.

It is perhaps too early to assess the results of an approach that, in part, replaces music appreciation and, in part, moves beyond the study of formed music to offer *everyman* an opportunity to participate in the creative processes of both composer and performer. There is recurring evidence of broader influence as the purpose, methods and values of this approach are considered and applied to education in general. We do not doubt that sharpened perceptual abilities will result and that a heightened ability to perceive will increase understanding which in turn will increase enjoyment which, in turn will...?

III

San Diego's graduate music curriculum also reflects an orientation toward doing. Both M.A. and Ph.D. programs stress research projects that call for experiment or, at least, active laboratory involvements.

Let me describe one current research project leading to an M.A. thesis, a study of one of the less-known theoretical writings of Mexico's late Juan Carrillo. Not only does this study require an English translation from the researcher, but also the development of documentary recordings that allow comparisons of the composer-theoretician's different pitch systems. The research will include recordings of microtonally-tuned pianos found at the Carrillo Foundation in Mexico City as well as recorded demonstrations of a quarter-tone guitar built for the UCSD music department according to Carrillo's own specifications. This particular study, although perhaps more exotic than most M.A. thesis projects, is still typical of San Diego's stress on doing.

Group performance courses are very much a part of the graduate program. The weight of the performance repertory falls on the side of new music, perhaps one of the more distinctive features of the program. At San Diego, older twentieth century pieces like Cage's *Amores* or Bartok's *Sonata for Two Pianos and Percussions* are presented as normal concert fare rather than as isolated ventures into the current century.

A description of a major graduate performance project of last year might be informative at this point. Last February 9, the department presented for the Los Angeles Monday Evening Concerts a program originally performed to celebrate the opening of the new campus of UCSD's John Muir College. This concert began with a performance of *Integrales* by Varese, Thomas Nee conducting, proceeded to a performance of *Antiphony IV (Poised)* by Kenneth Gaburo for amplified flute, amplified string bass, trombone, and tape, and closed its first half with the performance of *Pacific Sirens* for a fairly large improvising ensemble. Its performers are called upon to meld their sounds with those of a carefully filtered tape of the Pacific surf prepared by the composer, Robert Erickson, Ichiyanagi's *Appearances*, for instruments modified electronically in real-time, opened the second half of this concert followed by Ernst Krenek's apotheosis to Anton Webern, *An Instant Remembered*, for eighteen instrumentalists, taped narration with string ensemble, and soprano soloist.

Such an ambitious program is not brought off unless participants are both intensely interested in and informed about new music. In this particular project John Silber was the indispensable man, performing trombone in all works except the Krenek (which he conducted). But such a demanding program can be prepared only if a strong sense of group commitment is involved.[1]

This particular concert required an intensive integration of electronics with live performance but it was not atypical of the department's routine performing activities. The integration of electronics (in some shape and size) is often required for the realization of the UCSD faculty compositions. This creative love affair with electronics on the part of San Diego's faculty composers obviously encourages students to try something of the same sort or to perform other live electronic music. It is not surprising that Ichiyanagi's *Appearances* has undergone two different productions in the same number of years at San Diego.

The graduate program at UCSD is avowedly experimental in orientation, so the department is prepared to take its occasional lumps when things go awry, as when a recent quarter's-end concert by the music electronics performance seminar sent its large and sympathetic audience muttering into the streets during and after a several-hour endurance contest which offered admittedly debatable accomplishments. But of course controversy and failure must be part of experimentation.

Electronics and performance problems often mix as investigative research as well as theater and concert activity in San Diego. Robert Erickson's seminars ~~in~~ *Timbre* and *New Instrumental Resources* provide some opportunities for investigating acoustical and contact miking, filtering and modulating, as well as for the documentary recording of new performing techniques. So do project seminars in electronics conducted by Professors Campbell, Gaburo, and Oliveros—and problem-oriented seminars such as that offered in notation by Roger Reynolds.

Often the concert hall becomes the laboratory, as cooperative virtuosi like string bassist Bertram Turetzky appear in the concert hall well-wired. Real-time electronic experiments in the concert hall remain most problematical and one seems well-advised to check with the composer to see if everything "got through." At San Diego it usually does, the high batting average speaking well for careful preparation and astute technicians—although these are always, as everywhere, in too-short supply.

1. I would not slight the amazingly intense level of student and faculty commitment to the rehearsal and performance of traditional literature. Anyway, UCSD's concert and chamber choruses, its four-year-old civic-university orchestras led by Thomas Nee, an exciting chamber orchestra newly formed by Raphael Druian, and a very active program of chamber music performance (open to all qualified students and coached by graduate and faculty staff) under the coordinating guidance of Bertram Turetzky, would not allow it.